WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

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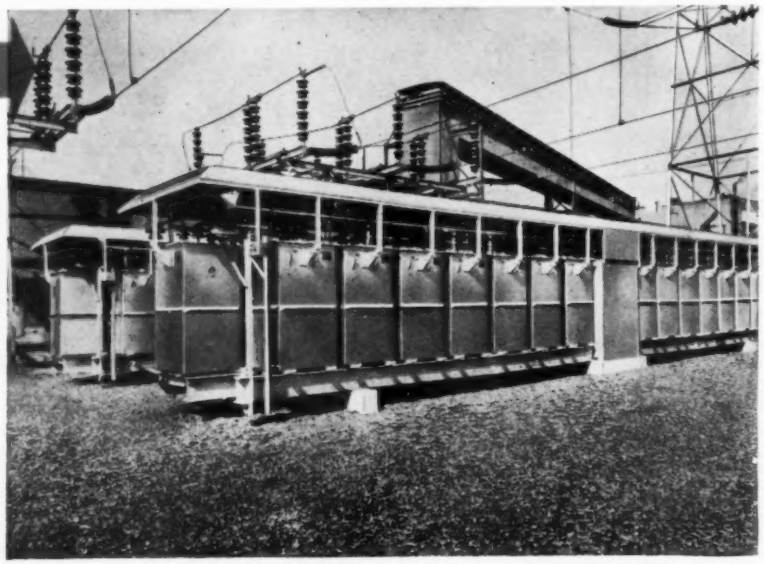

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Alternative-Power Economics

WHEN a choice is available between alternative sources of power the economic factors involved become a matter of keen controversy. On purely technical grounds any power source has to be examined on the two main considerations of availability, in which we should include reliability, and overall cost per unit generated. Political issues may also be involved, such as the impact on a country's economy or national security of developing one power source as against another or of depending on fuel or power purchased from abroad. Even so, any conclusions reached do not hold good for all time but have to be reassessed continuously in the light of technical, economic and political developments.

To exemplify, the battle between the steam turbine and the diesel engine has been waged all over the world and on the high seas, and the balance achieved is now being upset by the advent of the gas turbine. But even the gas turbine is dwarfed into insignificance by that challenging newcomer, atomic power, which bids fair to force a reassessment of the whole field of power generation.

When water power comes into the picture the layman may well be forgiven for regarding it as a direct competitor to thermal power generation—particularly by steam turbine. In a sense it is so, but the hydro-electric engineer knows that the question is not nearly so simple. Certainly the competition is not of the same nature as that involved in, say, the controversy —so rife in Great Britain—between gas and electricity for cooking and space heating. Many considerations arise that are peculiar to water power and which must be taken into account in arriving at a just balance.

One of the most important of these is geography. In Europe alone we have contrasts ranging from Great Britain and the Low Countries, which must always base their power requirements predominantly on fuel, to, say, Norway and Switzerland, whose power economies must always rest upon water. In short, an overriding factor in the assessment in any country is its relative water-power potential.

The geographical factor also arises in respect of plant location. A water-power plant must of necessity be placed where the water is available, and if this is remote from the load centre the power must be transmitted. A thermal station, on the contrary, can usually be placed near its load centre. Admittedly this may entail a transport cost for fuel, and if the fuel is not indigenous, a problem of national security arises; but these factors are not impossibilities of engineering although they affect the economic balance sheet.

These, of course, are questions of availability, and in this connection water power has other peculiar characteristics. A thermal station, from the technical standpoint, can store sufficient fuel to cope with any demand within its installed capacity for any length of time, the only availability problem being that of the time required to bring steam plant on to load. With water power, storage, although it can and must be provided, is relatively expensive, and operation is always conditioned by water availability. A series of dry years may seriously restrict output.

A further consideration in respect of availability is that of the full exploitation of the country's water resources. In our leading editorial last month we commented on some arresting figures given by Sir George Nelson which suggested that the world's water-power resources might be fully mortgaged in about 25 years. Such a conclusion, of course, is subject to the objections that can be taken to all generalisations, but it is significant that at least two of the papers given at the recent Brazil Sectional Meeting of the World Power Conference, a digest of which appears elsewhere in this issue, envisage the full exploitation of their countries' hydro resources in the fairly near future and a greater dependence on thermal plant. The papers we have in mind are those relating to Sweden and to Italy.

On the question of relative costs, too, the assessment is by no means as straightforward as would appear. On total cost per unit generated a water-power plant can undercut any thermal plant, save, possibly, in the case of combined power and process-heat installations, but that does not mean that thermal

power is out of court. To begin with, the balance of costs in the two cases is opposite; in a thermal plant the capital cost is relatively low and the generating cost high, whereas with a hydro-electric plant the reverse is the case. In other words, the bugbear of thermal generation is fuel cost, and of hydro power, capital cost. Then, too, the design of steam power stations is so nearly standardised that in any given country the total cost per unit is closely comparable between different stations; no such comparability is possible in the case of hydro stations because the natural conditions differ too widely.

These considerations should demonstrate the falsity of the view that the relationship between water and thermal power is either simple or one of internecine competition. In fact, the true picture is not one of competition but of correlation, and it is significant that in the many hydro-electric papers given at the recent Brazil Meeting the main theme is that of the correlation between thermal and hydro power. It is possible so to interweave the differing characteristics of the two forms of power that the combination offers a degree of availability and overall economy unobtainable from either source separately. Thus, on the one hand, the hydro stations can be operated so that the overall fuel consumption of the system is kept at a minimum; on the other hand, the thermal stations can be operated in relationship with the water reserves and can provide a supplement of firm power during periods of water shortage—on this account the capital expenditure necessary for water storage can be reduced.

The manner in which this correlation is effected must be determined from a detailed study of the system concerned; there is no general solution to the problem. For instance, in one system it may be more economical to take the base load on water power and to reserve steam power for the peaks; in another system, or even in the same system under different conditions, it may be better to reverse this procedure. The ratio between hydro and steam installed capacity is also a matter of engineering economics to be worked out for the particular conditions.

And what of atomic power? In his recent address to the British Association Sir John Cockcroft reported that nuclear reactions could provide mankind with energy for a millenium and that progress in both the engineering and the economic fields had been greater than one had dared to hope. It is notoriously rash to prophesy, but there seems little doubt that atomic power will eventually be a technical and commercial proposition. When that time arrives it seems to us that water power will reach a correlation with atomic energy on the same principles as that now obtaining with steam. Even then, unless the atomic scientist can find some way of circumventing the thermal cycle, with its inevitable loss incurred in the mechanical conversion of heat, the lowest overall cost per unit generated will almost certainly continue to be provided by water power.

Sir Adam Beck No. 2

THIS station, which was formally opened by the Duchess of Kent recently, will ultimately be equipped with plant capacity to the tune of 1,828,000 h.p. It is expected that five of the first twelve 100,000 h.p. waterwheel generators will be in operation before the end of the present year, with six more during 1955, and the final set ready for load early in 1956. A pumped storage reservoir, supplying separate generating plant, will provide an additional 228,000 h.p. for peak loads, thus bringing the total capacity up to 1,428,000 h.p. Four more 100,000 sets, making 16 in all, will be installed in the main station as required. In view of Ontario's demand for power these four remaining sets will probably be needed quite quickly, as it would seem that the load will overtake capacity before the International Rapids scheme, so long delayed, will be ready for operation.

Austria's Electricity Finance Problems

IN 1947 the Second Republic of Austria was able to consolidate the financial position of the country's electrical industry by means of a special law. This provided for the establishment of "Special Companies" for the construction of large power stations, and entrusted the "Provincial Companies" with the organisation of local supply.

For the establishment and operation of an interconnected system to link up the various power plants for the Special Companies, the "Verbundgesellschaft"—a joint stock company—was founded, whose shares are exclusively owned by the Federal State. The Special Companies are developing the power plants on the Drau and Enns rivers, and Kaprun power plant in the Hohe Tauern mountain range. A further Special Company was to build the Ybbs-Persenbeug power plant on the Danube; the power site, however, was seized by the Soviets and released only recently, so that constructional work can now be started. On the basis of parity, two companies were founded jointly with Germany which are developing the Jochenstein power plant on the Danube and the Braunau power plant on the Inn river. The interest of the Verbundgesellschaft in both companies amounts to fifty per cent. each, and runs up to £1·75 million in the case of the latter and to £1·3 million in the former. But all these funds were not enough for the establishment of large power stations, which became possible after the initiation of the Marshall Plan aid. During the period from 1950 to 1953 £30 million of E.R.P. funds were invested in large power projects, while a further £6·25 million were raised from depreciation reserves and surpluses.

Addition to Bridge River Plant

A FOURTH 62,000 h.p. generating unit has now been placed in service at this station, which is owned by B.C. Electric, and is situated 130 miles north-east of Vancouver. As a result of this addition the station becomes the largest utility-operated producer of power in Western Canada, having a capacity of 248,000 h.p.

At the opening ceremony, Mr. T. Ingledow, the vice-president and chief engineer of B.C.E., stated that the new generator set, which was similar to those already installed, had cost more than $4,000,000, and had taken two years to complete.

When fully developed, he added, the Bridge River system would have a capacity of 620,000 h.p. This station operates on one of the highest heads in Canada, the water from the river being diverted

through a 2½-mile long tunnel in Mission Mountain, and then dropped 1,200 ft. through penstocks to the power house on Seton Lake. Work first began on the project 27 years ago, and by 1934 the tunnel had been driven, and a small turbine installed to serve various mines in the adjoining Bridge River valley. But full-scale development was halted first because of the depression and then by the war, so that it was not until 1948 that the first 62,000 h.p. generating unit was placed on the line, to be followed in 1949 by two further sets. Some account of the six-nozzle Pelton turbines used in these sets was given in our September issue of 1953. Despite rapidly expanding industry and population, the company now enjoys a surplus of power—enough even for the host of new industries moving into the lower mainland. Meantime, work continues on enlarging the massive La Joie storage dam and on the construction of a new power station on Seton Creek, scheduled to open in 1956.

Volta River Survey

THE Preparatory Commission investigating the scheme for generating power from the Volta river, with a view to establishing a plant for aluminium production, have announced that much further work will have to be undertaken before a decision can be reached. The area to be inundated would, for instance, need to be carefully surveyed as the new lake would entail problems of health and sanitation, the full implications of which cannot yet be gauged. This survey will need to cover an area of some 3,000 sq. miles, and in addition such matters as labour, housing and communications would have to be investigated. The commission hope to have their reports completed by next year, and detailed consideration will then have to be given to them by the aluminium companies and the Governments concerned.

Isle of Harris Scheme

THE North of Scotland Hydro-Electric Board have now announced details of their Loch Chliostair, Isle of Harris, Hydro-Electric Scheme (Constructional Scheme No. 35) which will produce about 2·4 million kWh annually. The scheme provides for harnessing the waters of Loch Chliostair which has a catchment area of 2¾ square miles in the hills behind Amhuinnsuidhe on the northern shore of West Loch Tarbert about 12 miles from Tarbert, Harris.

A dam, 260 ft. long and 30 ft. high will be built at the outlet of the loch. From the dam, water will be led by a pipeline, 4,000 ft. long, to a power station with a capacity of 700 kW situated on the bank of the River Eaval into which the turbine will discharge. The small scheme will supply electricity to the Hydro Board's distribution system which has now been extended from Lewis into Harris. At present, there are at Stornaway diesel engined generators of 3,600 kW which produced 8·6 million kWh in 1953.

Tariff Problems in Ceylon

THE Ceylon Electrical Development Association is reported to be launching a campaign to enlist the aid of all industrial, commercial, agricultural and domestic users of electricity to fight for cheaper current. Hundreds of circulars are being sent out by the Association to consumers, reminding them that the second stage of the Ceylon hydro-electric scheme at Laxapana is shortly to be undertaken. If the present tariff rates on electricity continue to operate, it is argued, the vastly increased output of the Laxapana scheme will have to go to waste because the people cannot afford to buy it. Investigations conducted by the Association reveal that recent increases in tariff rates have already resulted in a drop in consumption demand. Before the increase, electricity was the cheapest form of lighting and fuel. The Association wants to see every home, even the humblest, with electricity, and rural electrification is regarded as another necessity.

In recommending the cutting of tariff rates, it is argued that increased national usage would save Ceylon millions of rupees a year by the gradual but substantial decreases on fuel oil imports.

Bids Invited for St. Lawrence Scheme

THE Power Authority of the State of New York and the Hydro-Electric Power Commission of Ontario have jointly called for bids for the first stage of this huge scheme. The work involves the construction of cofferdams, the erection of a bridge, and the construction of a dam (Long Sault) near Massena, St. Lawrence County, New York. About a million cu. yards of excavation will be required for the American portion of the contract, together with some 400,000 cu. yards of earthfill, rockfill and riprap, and the removal of 6,350 acre ft. of water from the area enclosed by the cofferdams.

The cofferdam enclosing the actual power-house site, located between two midstream islands, will be a Canadian responsibility, as also will be the dam required between Barnhart Island and the Canadian shore.

Both the power authorities are engaged in compensation negotiations with the upstream landowners whose ground will be affected when the river level is raised, and other negotiations are concerned with the allocation of costs.

Increase in Sweden's Electrical Output

THE output of electricity in Sweden during 1953 totalled 22,430 million kWh, an increase of 9·2 per cent. as compared with the previous year, according to the statistics of the Swedish Board of Trade. Net exports to neighbouring countries amounted to 298 million kWh, as against 130 million kWh in 1952.

The country's water and steam turbines had an aggregate capacity of 6,965,000 h.p., equivalent to 5,985,000 kVA. The corresponding figures for 1952 were 6,331,000 h.p. and 5,417,000 kVA. Within the total, hydro-electric output showed an increase of 9·3 per cent., whereas the steam-generated power rose by 7 per cent.

Out of the 19,109 million kWh utilised in Sweden during the past year, nearly half, or 8,277 million, was accounted for by large and medium-sized industry. Electro-chemical and electro-thermal industries consumed 2,995 million kWh, railways and tramways 1,483 million, electric steam boilers 1,222 million, small industry, handicraft, etc., 1,262 million, and agriculture 740 million kWh.

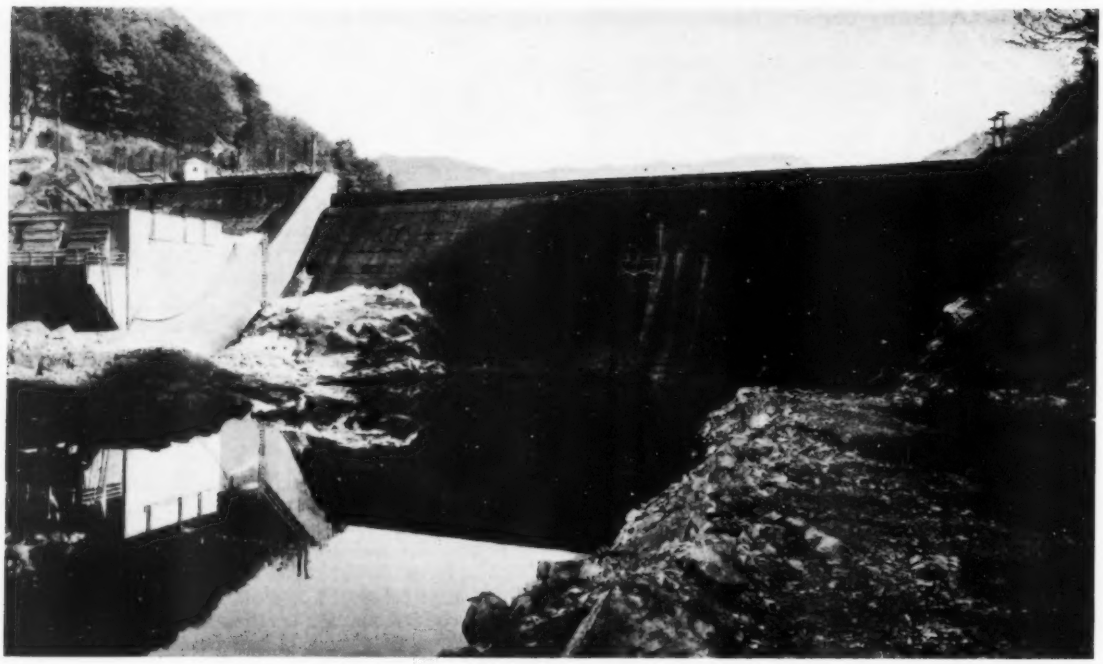

Fig. 1. Wilbur dam and power house before reconstruction

Rehabilitating an Old Plant

This article describes the modernisation of a medium-sized hydro-electric installation which was originally commissioned over 40 years ago.

WILBUR dam is situated on the Watauga river, about five miles east of Elizabethton, in Tennessee, U.S.A. The dam and power plant were constructed originally in 1910-12 by the Watauga Power Company, but in 1945 the property was acquired by the Tennessee Valley Authority, who have since modernised the generating plant and made considerable amendments to the dam. As originally constructed the plant consisted of a concrete dam with an overflow spillway and a power house located at the toe of the dam on the right bank of the river, the generating units comprising two double-runner horizontal sets and one vertical set, with a combined capacity of 3,700 kW.

To increase the storage capacity of the dam and at the same time augment the effective head, the spillway level was heightened to raise the normal pool elevation 5 ft., that is to elevation 1650. At the same time an additional 7,000 kW vertical generator was installed, and opportunity was taken to remove considerable quantities of silt from the forebay, and to lower the tailwater level by excavating a number of shoals downstream of the dam.

Silt deposited along the upstream side of the dam had reached an elevation of 1,630 ft., and the existing intake racks were embedded to a depth of 10 ft. This accumulation was removed by an air-operated dragline which was situated on the right bank, the silt being stirred up by the muck pan and drawn towards an existing 60 in. diameter circular sluiceway, the consistency being such that it could readily be handled in this way. This opening was sealed by a steel plate which was completely covered by silt, and consequently had to be removed by a charge of dynamite. The range of the desilting operations was extended upstream by changing the position of the sheaf block on the anchor cable. As the invert of the circular sluiceway was located at elevation 1615, and was useless for desilting purposes below this level, further depth was obtained by utilising the new No. 4 intake as the original concrete was cut out.

Later, a cut at a still lower elevation was made in the dam at the point where the No. 4 spillway is now located. This cut not only facilitated the removal of the remainder of the silt but was also necessary to enable the No. 4 intake to be reconstructed in the dry. Water passing out of the cut was carried over the work in progress below by a wooden flume.

It was desirable to remove the silt while it was still in the wet state, and this work was therefore pursued as expeditiously as possible; an attempt to

use a bulldozer was not successful, as the silt would not support the weight.

The spillway section of the dam has a length of 185 ft., the original crest being at an elevation of 1,640·8. Some 800 cu. yards of concrete were removed from the top and the elevation lowered by 9·8 ft. before reconstruction began. To effect this removal the downstream face was drilled with 2 in. dia. horizontal holes which followed a line at elevation 1631. These holes were spaced at 6 in. centres, and were extended to within one foot of the upstream face; they were quite effective in preventing overbreak. Four rows of vertical holes, 3 ft. apart and spaced at 18 in. centres, were also drilled across the weir. Each line of holes was charged and fired separately, beginning with the downstream row. Subsequently, angle holes, driven by a jackhammer, were blasted to obtain the desired cross section. Finally pneumatic paving breakers were used to trim off any protrusions and to obtain an even surface.

Concrete was placed in forms from the downstream side, being handled by a temporary stiffleg derrick located below No. 4 pier, and by a permanent stiffleg derrick mounted on top of the power house. When the intake structure had progressed sufficiently to allow the diversion slot to be closed, it was duly filled with concrete. The new spillway, with its crest at 1635, incorporates four radial gates, each 40 ft. long and 15 ft. 9 in. high, which raise the pool level to elevation 1650. The left bank abutment forms a junction with the access road, and the deck of the new structure provides a roadway across the dam to the switchyard on the right bank.

All visible concrete was refaced and the existing hoisting machinery for the intake gate was reconditioned and moved beneath the new deck. This deck is 10 ft. 6 in. wide and is composed of a 6 in. reinforced concrete slab, supported by 2 in. structural-steel beams and framing, which extends across the bays.

Each gate is operated by a fixed hoist, located on the deck, which is driven through gearing by a 5 h.p. squirrel-cage motor complete with magnetic starter and solenoid brake attachment. The reduction gearing effects a final speed of 27 r.p.m., resulting in the gate being raised or lowered at 2·65 ft. per min.

Fortunately it was not necessary to replace the whole of the intake gates, operating equipment and trash racks completely, but only those portions which were beyond repair. The hoists, which were easily reconditioned and were originally located on top of the intake section, were moved beneath the roadway deck. It was quite otherwise with the trash racks; the grating was warped and broken owing to the

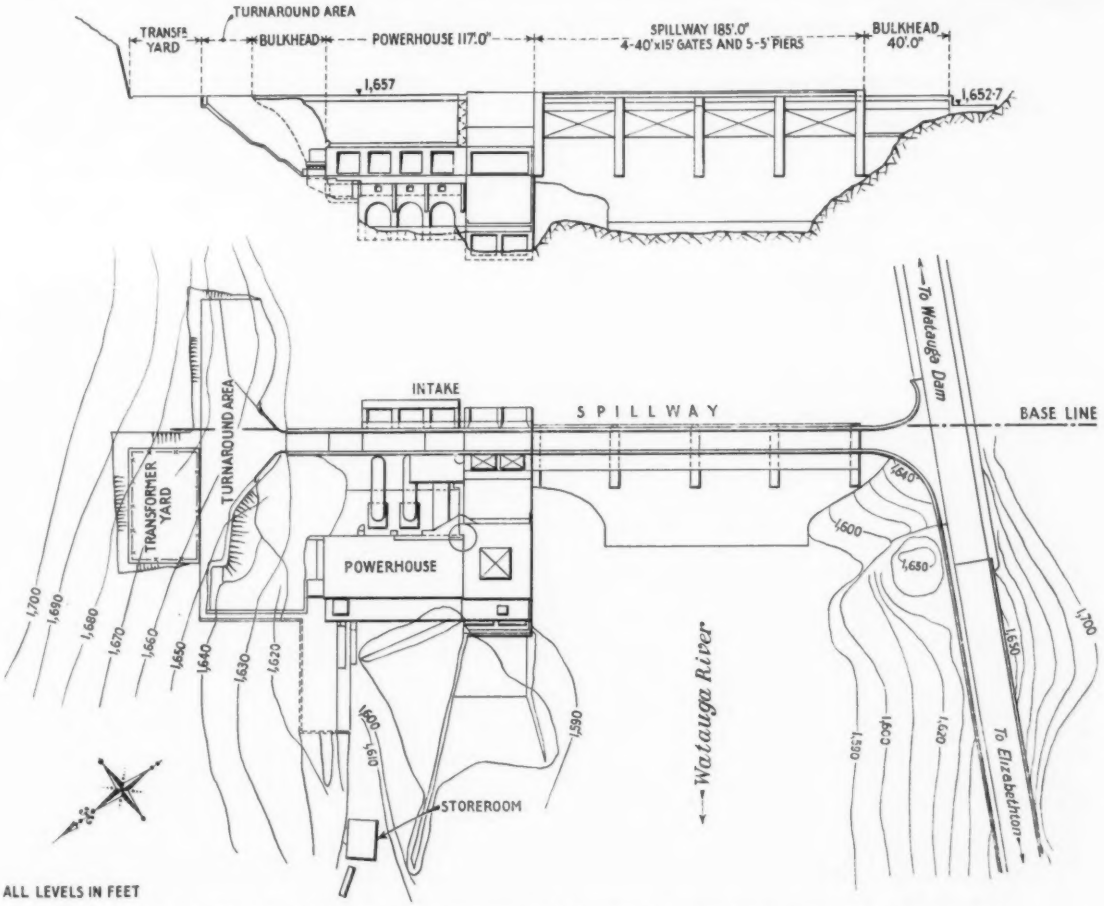

Fig. 2. Plan and elevation of reconstructed dam and power-house annexe for new unit

Fig. 3. Conditions after diversion slot was holed and silt removed from intake area

failure of the steel support beams, this, in turn, having been caused by deterioration of the concrete which left the beams without adequate anchorage. New grating was provided for the No. 1 and No. 2 trash racks, but sufficient good material was salvaged to make up a sound rack for the No. 3 unit.

The intake for the new unit is constructed in reinforced concrete and extends from the river wall of the power house to 37 ft. south along the baseline of the spillway section. Removal of the original concrete to accommodate this structure was effected in a similar manner to that adopted for the spillway section. In this instance, however, the horizontal line drilling was carried down to elevation 1618·7. Some difficulty was experienced in keeping a reasonable line as the concrete was apt to break off to an old joint. A total of 1,826 cu. yards of new concrete was required to complete this intake. For the new intake the gates consist of two radial units furnished by the Truitt Manufacturing Company. Before placing they were painted with hot bitumastic enamel. They are raised and lowered by the permanent power-house derrick, no other means of operation having been provided. This derrick has a capacity of 50 tons, and was supplied by the Equipment Corporation of America. In design the trash racks for the No. 4 unit are similar to those provided for the older units, and are supported by five horizontal, wide-flange beams bolted to anchor plates embedded in the adjacent piers.

The new power house is constructed in reinforced concrete; it is 37 ft. wide and extends 31ft. 1in. downstream and 22ft. 9 in. upstream from the centre line of the unit, and is made up of three floor levels situated at elevation 1582·9, 1593·15 and 1603·4. The upper room houses the generator and its control equipment, and the middle floor (el. 1593·15) the CO_2 fire-protection equipment, the raw-water piping and controls, the automatic greasing equipment and the air compressors. In the lowermost compartment are the station sump pumps and controls, the lubricating oil pump and storage tank and valves for the filling of the draught tube and the

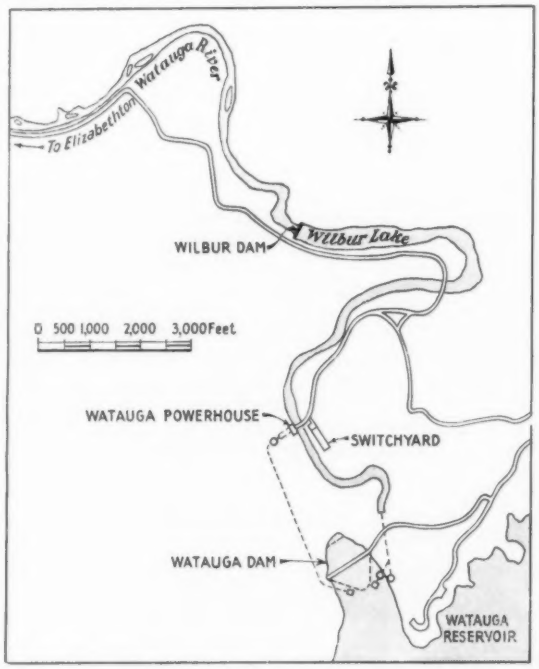

Fig. 4. Sketch map showing location of Wilbur in relation to the Watauga dam and powerhouse

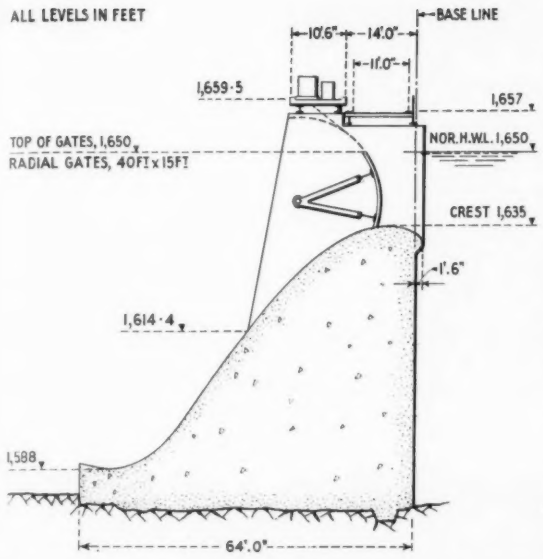

Fig. 5. Sectional elevation of reconstructed dam at spillway

drainage of the scroll casing. Access passages to the scroll case and draught tube also take off from this level.

The structure does not contain any steel framing and in consequence a relatively large amount of steel reinforcement was used—83 tons in the substructure (i.e. below the generator-floor level) and 73 tons above. The draught tube extends to the full width of the substructure and has a 3 ft. wall on either side and a 3 ft. splitter along the centre. The two openings thus formed are 14 ft. wide and 11 ft. 6 in. high. They are furnished with gates which can also be used as stoplog gates for the intake in the event of an emergency. This equipment was supplied by the Virginia Bridge Company, and consists of skin plates $\frac{7}{8}$ in. thick reinforced by four horizontal I beams and a number of vertical bracings—an I beam in the centre and two 6 in. channels and one 18 in. channel on each side. The entire gate assembly is welded.

The walls of the superstructure are 15 in. thick and are roofed with an 8 in. slab which is heavily reinforced around the perimeter. An opening in the upstream wall accommodates the windows and the louvres for the generator-room exhaust fans. A square hatch, 17 ft. sides, is provided and gives access to the generator room, and through this the unit components are handled by the permanent stiffleg derrick which has previously been mentioned in connection with the intake gates.

Excavation of the tailrace to which reference has been made involved the removal of some 15,000 cu. yards of unclassified material. This was done by conventional methods and reduced the elevation of the tailrace channel to elevation 1577·5. Unfortunately this reduced level interfered with the draught tubes of the old units, and a concrete weir had to be erected across their mouths with a top elevation of 1585.

The new No. 4 generator is of the vertical-shaft type, and is rated at 7,777 kVA, 2,300 V, 0·9 power factor, 180 r.p.m. A 60°F. temperature rise is allowed for at this output. It is driven by a fixed-propeller-type turbine which is rated at 9,700 h.p. when operating under a head of 58 ft. The power is conducted to a newly located switchyard through six 1,250,000 circular mil cables per phase. These cables are drawn through 6 in. conduits, and are carried along the exterior wall of the power house to the switchyard, which is situated adjacent to the right abutment of the intake structure at elevation 1656. A rigid truss-type structure of I beams and channels

Fig. 6. General view of refacing operations on spillway

has been adopted for the switchyard, and supports the bus and disconnect switches for the main power transformer bank and oil circuit breaker for the No. 4 unit. It also provides support for the metering transformers and the power take-off to the station service transformers. The main transformer bank (2,200/69,000 V) consists of three single-phase units each rated at 3,333 kVA when self-cooled, or 4,444 kVA with forced air cooling. In the general remodelling that took place opportunity was taken to amend the existing units so that they could be remotely and automatically controlled from the Watauga control room by means of an overhead multi-conductor, telephone-type cable, and the new Wilbur station is consequently controlled from that point.

The generator was supplied and erected by the Elliott Company, and is provided with a combined guide and Kingsbury flat adjustable-shoe thrust bearing. Six admiralty-metal coiled-tube oil coolers are provided for the thrust bearing oil bath, together with a remote oil-level indicator, two remote bearing temperature relays, one bearing thermal relay, and three resistance-type temperature detectors. The 16 in. dia. forged shaft is bored with a 4 in. dia. inspection hole along the centre line and carries a forged-on bearing collar. The lower-bearing bracket is a built-up welded structure, and the load of the rotating parts is carried on six radial arms.

The turbine was designed and manufactured by The James Leffel & Company of Springfield, Ohio. The draught tube liner extends 4 ft. 8 in. below the bottom flange of the curb ring and has an upper diameter of 9 ft. 10 in., while the bottom is in the form of an ellipse with major and minor axes of 11 ft. 11 in. and 9 ft. 10 in. A manhole 2 ft. 6 in. high and 1 ft. 8 in. wide is provided in the draught tubes to afford access to the runner assembly and to the concrete portion of the tube. The liner is fabricated from $\frac{5}{8}$ in. steel plate, which is reinforced on the embedded side with 4 in. by $\frac{3}{4}$ in. plating. Constructed in cast steel, the speed ring is finished to smooth lines and has a weight of 27,700 lb. It is provided with nine guide vanes, and has a diameter of 14 ft. 3 in. and an overall height of 6 ft. 8 in. It is constructed in two halves, which were transported separately and bolted together on the power-house roof before being lowered into position.

Control of the water flow to the runner is effected by 20 wicket gates, with integrally cast stems which

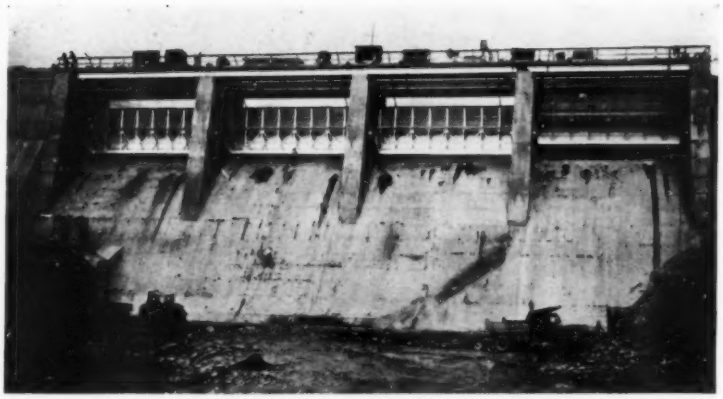

Fig. 7. Radial gates of new spillway

Fig. 8. Trashracks after removal of silt, showing damaged screen plates

Fig. 9. Constructional work on No. 4 unit

turn in bronze bushings. Each gate has stainless-steel sleeves that are grease lubricated from an automatic pressure system where they pass through the outer head cover and step into the bottom plate. The gate links are of cast iron, and are designed to break if undue force is exerted during closure. When in the closed position under pressure the openings between adjacent links are designed not to exceed 0·002 in. The cast-steel operating ring is actuated by two oil-pressure servomotors through the medium of the usual connecting rods. These servomotors have a bore of 15 in. and a stroke of 8 in. and work under an operating pressure ranging between 270 and 310 lb. per sq. in. A lock is provided in one of the cylinders, and is designed to hold the wicket gates in the closed position in the event either of the oil pressure falling below normal or the failure of the station service power supply. This lock is actuated by a 300 lb. pilot pressure line from the governor cabinet; it may be placed manually in the up position, thus making it inoperative, and only operates automatically when the main valve in the governor cabinet is open.

Fig. 10. Tailrace after dredging

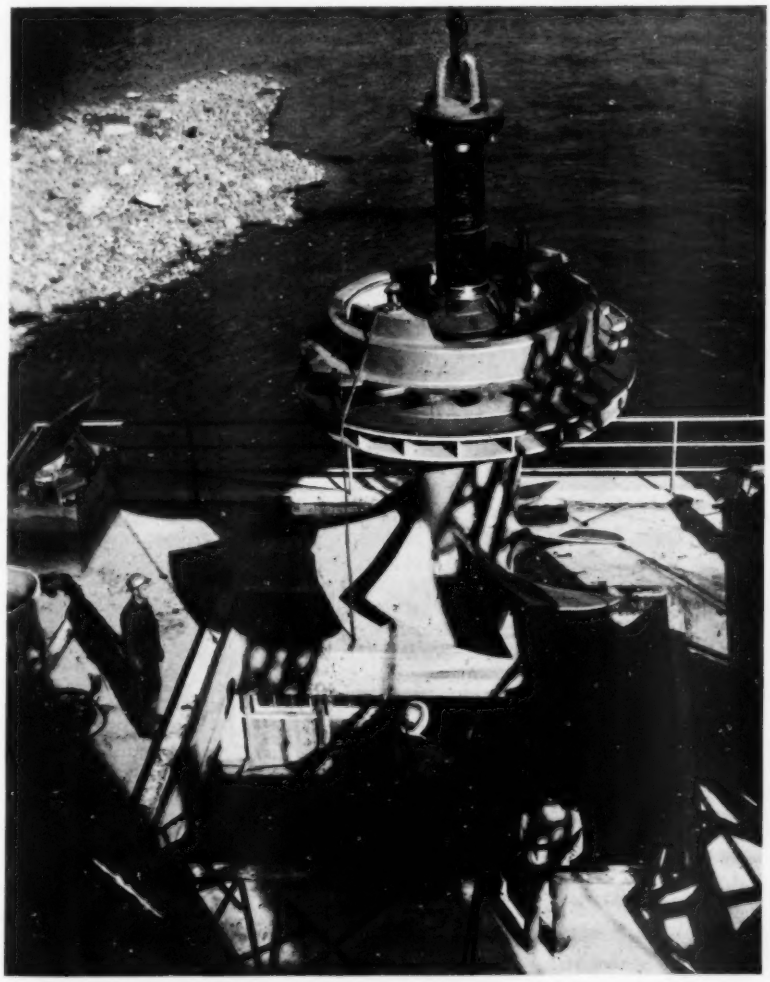

Fig. 11. Lowering Leffel turbine runner into position

The cover plate is of cast steel, and is made in two halves which were assembled on site, the diameter being 12 ft. 5 in. Also of cast steel is the inner head cover or crown plate, but in this case the construction is in one piece. It provides a bronze seat for the bottom bearing plate, the turbine guide bearing housing and the shaft stuffing box. The six-bladed runner has an overall height of 3 ft. $7\frac{7}{8}$ in. and an outside diameter of 9 ft. $7\frac{5}{16}$ in., this giving a designed clearance of 0·125 in. with the curb ring. All surfaces have a smooth finish and the blade ends have stainless-steel strips welded to them, half an inch thick. A stainless-steel plate is also welded on the lowermost side of each blade, 9 in. wide along the periphery and varying in width along the entrance edge.

The turbine guide bearing consists of a cast-iron housing, four cast-iron wedge plates and Insurok blocks, and adjustment wedges. These last-named are of bronze to withstand wear, and the contacting surfaces of the wedge plates and bearing housing are also fitted with wearing strips. The lantern ring and gland of the packing box are also of bronze.

Governing is effected on the relay valve "actuator" system, the necessary equipment having been supplied by the Woodward Governor Company of Rockford, Illinois. It is situated on the generator-room level beneath the downstream window assembly.

It should be noted that the modernisation of this plant and the incorporation of a new unit have been made possible by the additional storage capacity provided upstream by the Watauga scheme. The reconstruction was performed while Watauga was filling, thus affording complete control of the stream flow.

Fig. 12. Governor cabinet

Acknowledgements

These improvements to the Wilbur dam and power plant were designed and carried out by the Tennessee Valley Authority, to whom we are indebted for furnishing us with the above particulars of the scheme. Forty years is a lengthy period of time, even in the hydro-electric field, and it is natural that advantage should be taken of the new technique that has been evolved in the intervening period. In this case it has been possible to adapt an old scheme to produce over 100 per cent. more power, and yet usefully retain the old plant for standby purposes and low-load conditions. There must be many relatively small-scale plants which are similarly situated, and we consider this article to be of value in indicating how to set about a rehabilitation of this kind, and to show how profitable it may well be.

Irish Electricity Supply Board

The Annual Report of the Irish Electricity Supply Board for the year ended March 31, 1954, is one of continued progress. An increase of 131 millions in the number of units of electricity generated, as compared with the previous year, brought the total to 1,292 million units for the year. This was a growth of 11·3 per cent. The rainfall and inflow were somewhat below the average figures, but were much more favourable than in the preceding year. The output from the hydro stations was 533 million units, and from the thermal stations 759 million.

In connection with the Erne development, work continued on the dredging of the river channel between Belleek and Lower Lough Erne. Contracts were placed for the construction of the new weir at Portora, Enniskillen, for the regulation of the level of Upper Lough Erne, and the construction of the new road bridge at Belleek. Work under both contracts had begun by the end of the year. All the main parts of the turbine for the second 10,000 kW set at Cliff were delivered and erection commenced in January, 1954. It was expected that this set would be in commission in 1954.

On the river Lee the excavation of the river diversion channel at Inishcarra was almost completed and the construction of the portion of the dam, which it is necessary to erect before the river can be diverted, was in progress. Work was started on the excavation for the foundations for the dam and power station. At Carrigadrohid, the first stage in the cofferdamming of the river was finished and the excavation for the dam foundations was proceeding. The excavation for the stilling basin below the sluices was completed.

Tenders for the civil-engineering work for a 4,000 kW development on the river Clady had been received and work on site was expected to commence in May 1954. Specifications for the generating plant and penstock were almost completed and tenders were about to be invited.

The average flows at all the hydro stations were below the normal, being generally between about 75 per cent. and 85 per cent. of the long-term means. The distribution of the flows throughout the year was, however, favourable for power generation. The utilisation of the flow available for power production was in the region of 100 per cent. at all stations except at Cliff power station, where the second unit was being installed.

Turning to investigational work, the Report states that further tests of the underground conditions at the site of the dams for the Avonmore River Development project, Co. Wicklow, were completed and the results were under consideration at the end of the year. The feasibility of the hydro-electric development of the Cummeragh river, Co. Kerry, was under consideration, and the preliminary scheme for the development of the Troc Waterfall, Co. Kerry, which was prepared in 1944 was under review in the light of present-day conditions and building costs. Preliminary investigations were also in progress on the economy of the hydro-electric development of the Flesk river, Co. Kerry.

The collection of data with a view to the investigation and possible later development of the further water-power resources was continued. The total number of undeveloped rivers under observation, excluding the Lee and the Clady, was seventeen.

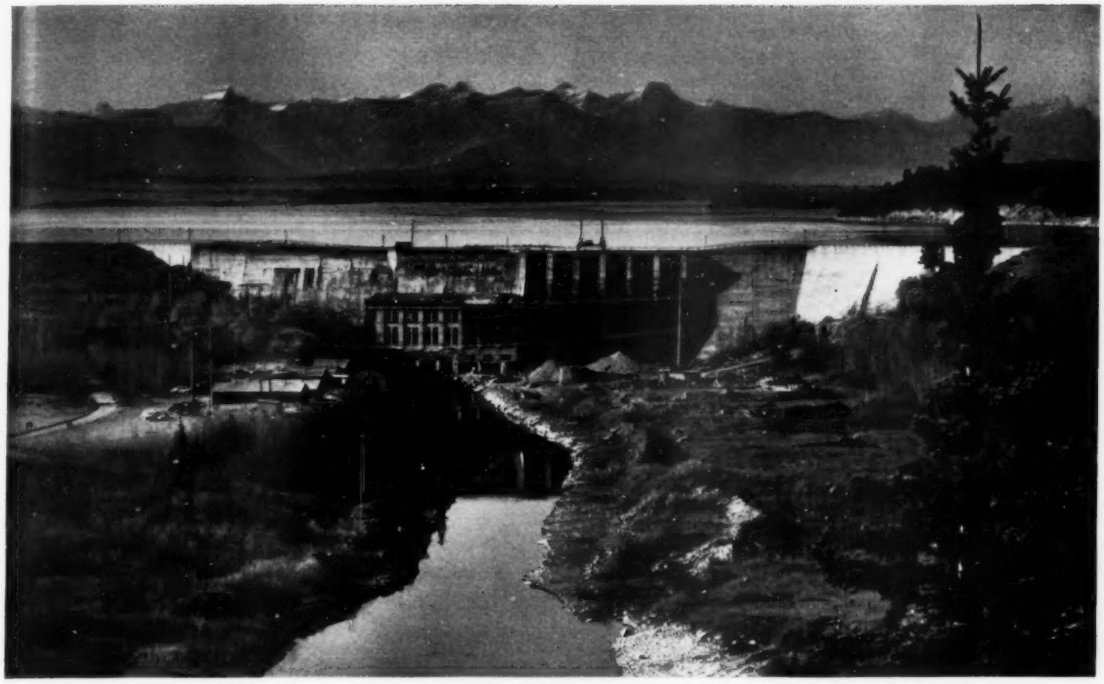

Fig. 10. General view of Ghost plant

Hydro-Electric Power in Alberta

An account is given of the activities of Calgary Power Ltd., with special reference to the new Spray River plant and the scheme of automatic and supervisory control which has been introduced.

PART TWO

Automatic and Supervisory Control

Mention has already been made of the fact that Calgary Power Ltd. operates eight hydro plants totalling 160 MW capacity. Originally the changeover to automatic control was conceived as a measure to save personnel and so secure more economic operating costs, and this conception has been fully realised; but system disturbances, followed by periods of low frequency, often unduly prolonged by the jamming of the intercommunication circuits by anxious operators and other members of the staff, gave additional weight to having a system control centre at which a single operator, fully and immediately informed from all points, could take prompt appropriate action without having to institute any fact-finding enquiries that would necessarily involve delay.

The 12 MW Barrier station, completed in 1947, was designed as a semi-automatic supervisory controlled plant from the outset, the supervisory channel being a power-line carrier. This single unit, with its simple switching, is well adapted to remote control; automatic synchronising is provided for the generator and feeder circuit breaker. Results proved so successful that the 20 MW Cascade plant was converted in 1949; the equipment here is rather more complex as it was also necessary to control a three-unit pumping plant and a dam supplying water to a canal serving the power plant. The newer Spray development was designed from the beginning for automatic and remote control; in this scheme the control at the Three Sisters plant determines the rate of flow through the 3,600 h.p. turbine and hence the quantity flowing into the canal serving the Spray and Rundle plants. The output from the Three Sisters is fed through a single circuit breaker to a 41 kV network which serves a colliery and cement works. At the Spray plant the generator output goes direct to the transformer without the intermediary of switches and is controlled by a 138 kV oil circuit breaker on the high-tension side. This plant is also linked with two 138 kV feeders. The Rundle plant is rather more complicated with respect to automatic switching as the generator is required to serve both the 41 kV and 138 kV systems.

All the controls for the Cascade, Three Sisters,

Spray and Rundle plants are functioned over leased telegraph carriers, but the Kananaskis plant is direct cable controlled. At this last-mentioned plant a recently installed unit is automatically controlled but the two original machines are remote manually controlled from system control centre. This centre is actually located at the Kananaskis station and will ultimately incorporate controls for 20 generating plants and substations. In its present state of development, it is noteworthy that the cost of the automatic and supervisory control equipment, including the intercommunicating lines, is substantially less than the estimated cost of the housing accommodation that would have been necessary for the manual operators.

The Equipment Used

At each station the automatic equipment provides for the starting and stopping of the turbo-generators and for synchronising across all circuit breakers where required. As already stated, the Three Sisters plant has provision for fully automatic operation and the other plants for semi-automatic control, all this control being under the initiation of the supervisor in charge at the Control Centre. The following switching requirements are met:—

(1) If the bus is alive, the controls enable the generator to be started, synchronised and the circuit breaker to be closed.

(2) With the bus dead, the generator can be started and closed directly on to the bus.

(3) If the bus and line are alive, the controls enable a feeder circuit breaker to be synchronised and closed.

(4) If the bus or line is dead, the controls enable the feeder circuit breaker to be closed directly.

When the Three Sisters plant is on fully automatic operation it is controlled by a water-level device designed to maintain a constant level in the canal system. This device consists essentially of two electrodes and a relay, the separation between the electrodes determing the limit at which the turbine gates open and close. Supporting action and protection is afforded by two floats which are set to operate an alarm if the electrode control fails and then lock out the plant if the failure persists. Upon receiving a start impulse from the Control Centre, the unit runs up to speed, synchronises and picks up load to full gate opening; when stopping, the governor is closed down and the oil circuit breaker for the generator trips out as soon as the gates reach the no-load position. In normal operation this cycle takes place four or five times a day. Each plant is completely self-protected independently of the operator in the Control Centre. Although alarm indications are sent out to the Control Centre when the plant is under automatic operation, this alarm is backed up by protective devices inherent in the equipment itself. These devices ensure:—

(1) A shutdown if faults which may be self-correcting occur, and

(2) A complete lockout in the event of faults of a more serious nature, e.g., high bearing temperature, generator field failure, and so on.

Synchronising. Apart from Rundle, all the plants are required to synchronise between two voltage sources only. The automatic synchroniser is connected to the generator and line potentials to close either the generator circuit breaker or the line circuit breaker, thus greatly simplifying the controls. At Rundle, three voltage sources and five circuit breakers are involved, necessitating the automatic transfer of the synchroniser connections. This arrangement enables the operator to initiate the closure of any or all circuit breakers without waiting for the synchroniser to complete any

Fig. 11. Cascade plant showing canal, wood-stave pipeline, surge tank and power station

Fig. 12. Cascade wood-stave pipeline and surge tower

operation he has called for, and this frees him to give his attention to other duties—a particularly valuable feature during periods of trouble.

A description of the equipment in use in this scheme was given in a paper contributed to the American Institute of Electrical Engineers, to which interested readers are referred.† In effect, an automatic synchroniser is provided with relays which enable it to be used in turn for several circuit breakers in a pre-determined sequence, with overriding features designed to permit manual synchronising if required. The generator is given first priority over the synchroniser and the latter is disconnected should a circuit breaker fail to close within ten minutes.

Governors. Earlier installations employ conventional governors with added automatic attachments, but the later installations have all been provided with cabinet governors designed for automatic operation. The former control the starting by slowly raising the load limit under the control of a timer. The latter are equipped with a two-solenoid starting sequence. When the first solenoid is energised, the turbine gates open to a preset position to bring the unit up to speed. Closure of the generator circuit breaker picks up the second solenoid to permit full gate opening.

There is a great variation in response to speed setting between governors. The cabinet governors respond rapidly and speed match with minimum delay. The Spray plant, with cabinet governor, has synchronised within one minute to the system with falling frequency. This is important during periods of system trouble. The conventional governors with speeder springs have taken four minutes to synchronise under similar conditions.

On completion of a stopping sequence, the automatic governors shut off the oil pressure and lock the turbine gates closed. Two locking schemes are used: the cabinet governors have a mechanical latch mounted on one of the servomotors to engage the operating shaft and hold the gates closed, while the governors mounted integral with the servomotors have a brake band and drum to lock the gates after shutdown.

Speed Matching. Speed matching is performed by two three-phase motors acting in opposition through a differential gear machanism. The output of this mechanism alters the governor speed setting to reduce the speed difference between the two sources to be synchronised. One motor is energised by the generator

Fig. 13. General view of Horseshoe station

potential, the other from the line or bus to be synchronised.

Speed matcher requirements are exacting in automatic plants. Not only must the two speeds be matched but they must be brought together in successive overshooting to operate the automatic synchroniser. Motors with good synchronous characteristics are necessary. Early difficulties with speed matchers resulted from their failure to take the speed through synchronism. It was necessary to slot the rotors of the induction-type motors supplied to obtain synchronous characteristics. Synchronous motors give rapid operation and, with the relatively slow response of the governor, serve to overshoot the speed first in one direction then the other at increasingly diminishing rates.

Automatic Load and Frequency Controller. Time and load apportionments are maintained by automatic load and frequency controllers which were initially designed to control units at one hydro station only. They were later improved and adapted for use on all main generating units. These controllers operate to divide the load among the controlled units in proportion to the generator capacities, but to meet load and forebay regulation requirements they can be set by supervisory control to operate any unit at or about 60, 80, 100 or 120 per cent. of its efficient load.

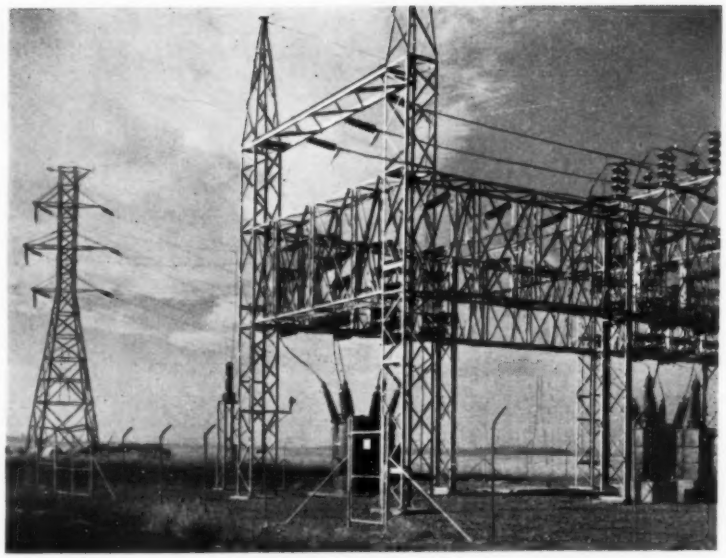

Fig. 14. Typical 132 kV transmission tower and substation

A mechanical clock with a contact-making device and photoelectric relay sends an accurate 1 sec. signal every 20 sec. (over a telephone simplex circuit) to the load controllers located in each plant. Each controller has a rotating arm driven by a telechron motor at the rate of one revolution every 20 sec. Contacts, operated by the arm, have a position dependent on the load carried by the generator and also upon the per cent. load apportionment selected (remotely) by the Control

Fig. 15. General view of Kananaskis plant showing dam, intake and power house

Fig. 16. Bearspaw plant in course of construction

Centre operator. The relative position of the arm and contacts at the time the master clock pulses are received determines whether the controller will operate to raise or lower load. Failure of a plant to receive these signals leaves the unit operating at the last load setting which can be changed at the will of the Control Centre operator by supervisory control.

If a load adjustment is required the special governor mechanism is operated for at least 25 sec. A large temporary change in governor setting is made for this interval and coincidently the governor load-setting device is slowly adjusted. This combination gives quick response and stability.

The operator can also use the load controller to float a given unit. The controller then operates to drop the load on that unit at a predetermined rate, but only provided that the system speed can be maintained. The controller will drop all load but will prevent the unit from motoring.

Interlocks permit the manual load-control switch on the remote switchboard, or direct supervisory operations for raising or lowering load, to supersede the automatic controller at any time.

Penstock Valves. Spray and Cascade have penstock valves that must be opened before energising the turbo-generator controls. Valve opening is initiated by the starting impulse from the Control Centre which opens a bypass to flood the scroll case. As the scroll case is flooded, a float switch energises a relay to close the air vent and open the main valve. A full-open limit switch on the valve energises the turbo-generator controls.

Supervisory Features. The Control Centre has an alarm system to indicate any change in conditions at the remote plant. The alarm consists of a loud single-stroke gong followed by a buzzer. Name-plate escutcheons, located at the top of each benchboard, are illuminated to direct the operator's attention to the benchboard of the plant sending the alarm. The escutcheon and buzzer remain energised until cancelled by the operator. In addition to the individual plant cancel buttons located on each benchboard, the operator's desk is equipped with a master alarm cancel to reset alarms originating at any plant. The operator also has a master indication check button to initiate a checking indication cycle on any plant.

Also controlled from the telephone swichboard are relays which are located in the remote plants and which are used to interconnect telephone lines. This switching was installed to permit communication with remote plant staff in the event of failure of normal circuits. The control and lamp indication of these relays is accomplished through the supervisory controls of the plants concerned.

Circuit Operation. The Supertrol method of supervisory control is employed for those plants which are controlled over carrier channels. Individual push buttons, or push buttons combined with selector switches, are provided. When an operation is called for, a sequence of four audio tones is transmitted to the remote plant. The equipment is adjusted to send the four tones in one second. The received signals are sorted by a relay network which then closes the selected final relay. The code employed consists of four pulses with four frequencies available.

Lamp indications confirming operations are obtained instantly by transmitting one of two audio tones from the remote plant. Upon arrival at the dispatching station, these signals pick up or drop out the selected lamp-control relay. Lamp indications for trouble alarms or other involuntary operations are obtained differently. At both dispatching and remote stations, relays are provided for each lamp function. A change in position of any of these relays at the remote station starts the operation of a stepping relay. This in turn checks the position of every relay in the group and transmits one of two audio tones for each step. At the dispatching station these tones drive a similar stepping relay and also pick up or drop out the connected lamp-control relays.

Circuits are provided which open the power to all

indicating lamps on a benchboard if the stepping relay at the dispatching station gets out of step with the one at the remote plant. Lightning discharges and other spurious interference often operate the tone-receiving relays. Formerly this caused the dispatching-station stepping relay to advance from its normal position and resulted in a " black board." The circuits, as now changed, require a pulse of ½ sec. or longer to step the dispatching relay from its normal position. To accommodate this, circuits at the remote station were modified to send a pulse of about 1 sec. duration for the first step of a stepping-relay cycle. The stepping rate for the remainder of the cycle is adjusted to 7 points per sec.

Telemetering is of the impulse-duration type. The transmitters contain primary instruments which are scanned photoelectrically. Every 5 sec. contacts close for an interval which is proportional to the quantity metered. The signal is transmitted to the dispatching station as an audio tone. In the telemetering receivers capacitors are charged to a voltage proportional to the length of pulse. The voltage is applied to the grid of an electron tube and controls current flow through a meter in the plate circuit. Megawatts and megavars are transmitted continuously for each generator. Other readings of electric or hydraulic quantities in the remote plant can be obtained one at a time when called for. These are received on individual meters at the dispatching station. The response speed of this method of telemetering is limited by the 5 sec. scanning interval. While fast enough for normal conditions, it is slow to follow system disturbances.

Megawatt-hour readings for the generators appear on counters at the dispatching station. At the remote stations, the megawatt-hour meters are equipped with contact-making devices which operate relay circuits. The relays limit the outgoing signal to about 1 sec. duration. Pulse limiting was developed when it was found that the long pulses often became broken by transmission interference into a number of smaller pulses.

A large number of control relays are installed in the supervisory cubicles and in the rack-mounted units. For example, the single-unit Rundle plant uses 106 relays at the dispatching end and 193 relays at the remote station. All supervisory relays are of the plug-in type which greatly facilitates maintenance. Other devices, such as stepping relays and timers, are connected through cables and plugs and may be replaced with spare units in a matter of minutes.

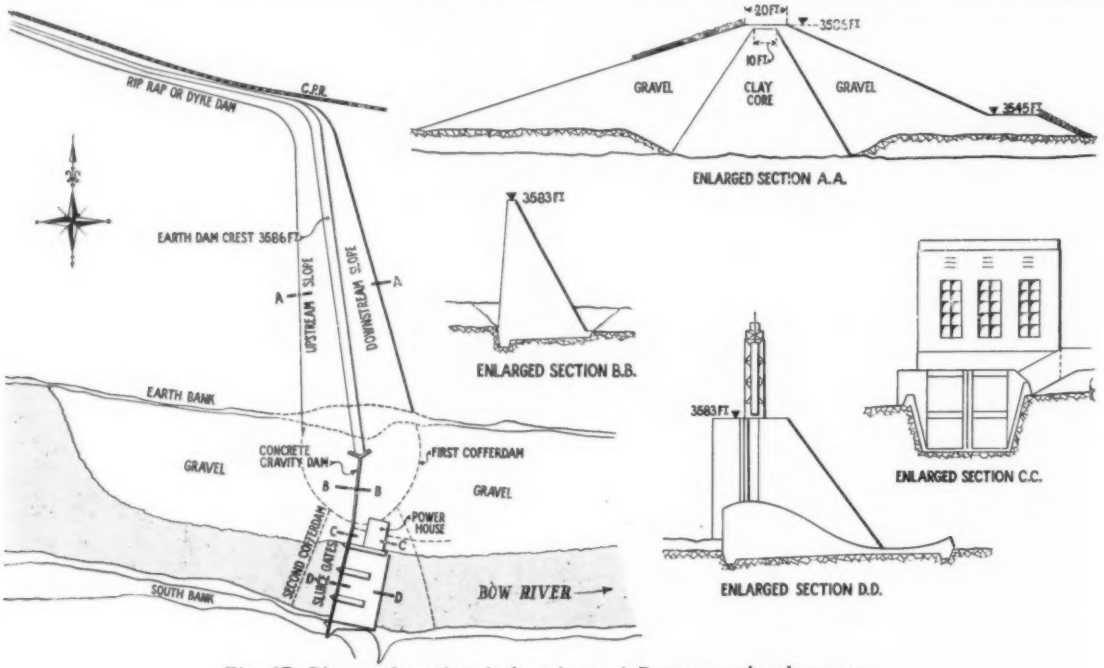

Fig. 17. Plan and sectional elevations of Bearspaw development

Channels. The Barrier supervisory control is operating over a duplex power-line carrier channel about 6 miles in length. Power-line carrier was chosen for this application despite the short distance as it was desired to obtain experience with this type of transmission for future use. The requirements for a control channel were found to be more exacting than one required for voice communication alone, a higher signal-to-noise ratio being required. While this carrier channel was initially operated without line traps, it was soon discovered that switching on adjacent lines would upset the subcarrier levels, at times rendering the supervisory inoperative. Line traps were installed and have served to isolate the carrier section from the effects of external switching.

The Spray plants (Three Sisters, Spray, and Rundle) and Cascade are controlled over leased telephone-carrier channels. These are duplex circuits and give the equivalent of four-wire operation. Power-line carrier was not considered practical for the control of these plants which feed into a closed-loop transmission network, as power-line carrier would require a complicated network of traps and bypass units uneconomical for the short distances involved.

One three-channel carrier and one single-channel carrier are used to control the four plants. Spray, Three Sisters, and Cascade are controlled over the three-channel carrier system operating on two metallic pairs. The high-frequency channel operates over 18 miles of open wire line to control the Spray plant; the medium-frequency channel operates over the same circuit plus a six-mile extension to control the Three Sisters plant. Cascade is controlled over the low-frequency channel operating on a second metallic circuit of about 24 miles in length. The three channels are stackable, that is, all carriers can operate on one pair in the event of trouble on the other. The Rundle carrier operates on a third pair with provision for transferring to the Spray—Three Sisters metallic in the event of trouble. Rundle and Cascade carriers operate at the same frequency and cannot be superimposed on the same circuit.

Failure of both metallic circuits to a remote plant is quite possible and design work is now completed to provide for the control of any plant over frequency-modulated radio. This radio network normally is used for communication and will be employed to provide intermittent control of any plant. If space radio proves reliable it may replace the metallic circuits and carrier channels.

Carrier Telephone and Audio Monitoring. Ordinary telephone communication is carried on voice-frequency channels applied directly to the metallic circuits. For test purposes, units have been designed and installed to permit coupling some telephone equipment to the carriers on a four-wire basis. Electronic coupling is used to make subcarrier levels independent of telephone connections. The units also incorporate interlocks to prevent operation of the microphone circuits while the plant is being operated on remote control. The interlocks are required since the voice frequencies of the carrier telephones cause operation of the frequency responsive units. Telephone alarms at the remote plant and telephone indicating lamps at the dispatching station are operated as functions of the various supervisory controls. The carrier telephones are provided primarily for the use of technicians when testing operation of the controls.

The dispatching coupling units drive loudspeakers located near the various benchboards and provide for monitoring of outgoing Supertrol signals. The units do not receive the continuous audio tones used for channel monitoring. Push buttons permit the operator to transfer the audio monitoring for any station from outgoing tones to incoming tones. The operators find the monitors useful as confirmation of correct circuit operation.

Monitoring and Switching of Carriers. Each plant controlled over carrier telephone is provided with at least two metallic telephone circuits. Provision is made for the manual transfer of any carrier from one metallic circuit to the other. In addition to this, Calgary Power Limited developed a scheme for continuous monitoring of transmission and automatic transfer of the carriers. This is accomplished by the transmission of an additional audio tone over each carrier being checked. The tone is generated at the remote plant and transmitted over one carrier to the dispatching station. Here, special repeaters derive two independent outputs, one used to operate control relays and the other fed into the carrier returning to the remote plant. At the remote end the returned signal operates another set of control relays. This particular arrangement was selected to avoid the cost of an additional signal generator at the dispatching end. Failure of the normal monitoring tone to arrive at either dispatching or remote ends causes transfer of the carriers to the emergency line and also causes replacement of the normal monitoring tone with one of different frequency. Successful arrival of the new tone at both stations holds the switching relays in the new position. In general, loss of a monitoring tone initiates a sequence of timed transfers at both ends, a sequence which is stopped as soon as the carrier circuit is restored. Transfer of the carriers, as a result of momentary interruptions of the monitoring tones, is prevented by the timing of the control devices. Such interruptions occur frequently as a result of transmission interference or of operation of protective devices.

Pilot lamps are provided on the various benchboards to indicate arrival or failure of the carrier and to show which line is being used for transmission. Operation of the equipment also rings the supervisory alarm. Push buttons are provided to initiate transfers for test purposes. This scheme can be readily extended to three or more metallic lines.

Emergency Control. Present supervisory controls are designed for operation over duplex channels. Operation over the simplex frequency-modulated radio network is made possible by circuit changes effected by the emergency control units. When using this control the operator first selects the plant by sending a coded call over the frequency-modulated radio. For this purpose the call has two pulses, each of which consists of two simultaneous tones. The emergency control equipment at the remote plant will be picked up only provided that the carrier switching equipment indicates failure of the telephone carriers. After setting up the emergency control circuits for the plant, the operator can call for any operation by using the normal supervisory controls. This signal will be transmitted over the frequency-modulated radio channel. Upon completion of the calling signal, the local transmitter will be turned off automatically and the remote one turned on. Return signals for lamp indications and telemetering will then be received. Timers hold the equipment in this condition long enough to obtain the indications and then return all equipment to normal. Every operation called for must be preceded by the station-selection call. Pilot lamps indicate certain steps in the operation of the emergency control units.

Emergency Power Supply. The Control Centre is being equipped with an unfailing source of a.c. power to supply the electronic equipment and main floor lighting. The power is supplied from a 10 kW 120 V 3-phase alternator, motor driven from the battery circuit with the battery floated from a 15 kW charging set operating from the main station service. Failure of the main supply cannot affect the power to the supervisories.

Operating Results

Only one pronounced system disturbance has been caused by the controls and that was initiated by the failure of a technical operator to disconnect the controls to the spherical valve at Spray when the plant had been placed on manual control after a power conductor had contacted a telephone circuit in a high

gusty wind. The circuits have now been rearranged to avoid such an occurrence. Otherwise most of the troubles experienced were trivial, easily corrected, and had no adverse affect on power services. As a source of power trouble the supervisories can be practically eliminated, as failure of supervisory devices leaves a plant operating as last dictated by the Control Centre operator who then directs a technical operator to report to the plant. Large operating savings through the installation of these devices can be made. Maintenance requirements have been small. The following maintenance schedule is considered to be quite adequate: test and adjust levels of carriers and subcarriers bimonthly; test and replace tubes as required every four months; clean and adjust relays and other components yearly. A few of the relays in very constant service may require additional attention.

It is worthy of note that this system of controls has been installed during a period when Calgary Power Limited increased its number of hydro plants from four to eight and that the technicians (who were relatively untrained) devoted most of their time to assisting in the installation of the plants and their controls.

The total capital expenditure on the automatics and supervisories to control the six hydro plants and for the system Control Centre approximated $250,000. Costs varied from $20,000 to $45,000 per plant. The larger amount for the conversion of Cascade includes $6,000 to convert the pilot valve.

Owing to the locations of the hydro plants it is necessary to provide housing and services for plant staffs. It is estimated that housing costs for additional staff to operate the plants would have amounted to $350,000. Though housing may not be a factor with some utilities, in the present instance they would have more than offset the cost of the controls.

As attended plants, the six stations and system Control Centre that now comprise the "automatic-supervisory system" would have been staffed by 35 operators, two relief operators, four floormen and six maintenance men (exclusive of maintenance crew), a total of 47 men. With salaries, fringe benefits, and so forth, averaging $5,200 per man per annum, operating labour costs would be $244,400 per annum (excluding superintendents and maintenance crew).

The automatic-supervisory system now employs five Control Centre operators, nine technical operators, a relief operator, and four floormen, a total of 19 men. Salaries, fringe benefits, and so forth, amount to about $98,000 per annum (excluding superintendents and maintenance crew).

Carrier rentals are $3,770 per annum. Replacement material costs are almost negligible; tube replacements cost about $250 per annum, and other materials an equally modest amount. The saving in operating costs is therefore about $142,000 per annum.

Acknowledgments

We are glad to acknowledge our obligation to Mr. A. W. Howard, General Manager of Calgary Power Limited, for so kindly affording us facilities to inspect the various plants under his charge.

Liberal use has been made of a paper* presented to The Engineering Institute of Canada by Mr. G. V. Eckenfelder and this source of information is gratefully acknowledged. Mr. Eckenfelder, throughout the whole of the constructional period of the Spray development, was resident engineer of the Montreal Engineering Co. Ltd., which was responsible for much of the engineering work on the various projects. For the data relating to the automatic and supervisory control of the Calgary plant the writer is indebted to a paper† presented to the American Institute of Electrical Engineers by Messrs. T. E. Cardell, M. W. Clarke and H. Randle, of Calgary Power Ltd., and this indebtedness is also gratefully acknowledged.

Our obligations to Mr. H. Randle are extended still further, not only for the trouble he took to explain the technological features of these plants but also in conducting us around the Spray development personally—a kindness which necessarily placed a heavy tax on his time. Not content with this, hearing that we had never been to Banff, he conspired with Mr. W. Ross, the Public Relations Director of Calgary Power Limited, to ensure that we should not leave Canada without witnessing the glories of that wonderful region.

* "Spray River Hydro-Electric Power Development." By G. V. Eckenfelder, M.E.I.C., presented to the 66th Annual Meeting of The Engineering Institute of Canada, at Vancouver, B.C. May 1952.

† "Automatic and Supervisory Control of the Calgary Power Ltd. Hydroelectric System—Some Design Features." By T. E. Cardell, M. W. Clarke and H. Randle. Presented to the American Institute of Electrical Engineers. January 1953.

Making Use of the Technical Press

A technologist in a responsible position in any field of endeavour must keep himself informed of current developments. Perusal of technical journals is one of the best and most convenient ways of keeping up-to-date in these matters.

Heavy demands are made on the time of, say, consulting engineers, the chief executives on site, civil-engineering contractors or others concerned with water-power developments, so that they have little leisure to sift out the information contained in the many technical journals which deal with their subject. Yet a large amount of this information material can be of use and the desirability of recording and classifying it is not to be gainsaid. This is admittedly difficult. The problem is discussed in the June issue of our American contemporary *Machine Design* which for purposes of illustration, describes the use of technical journals in an information service carried on for several years in a medium-size manufacturing plant in the United States.

Before the service was started a survey was made of the many periodicals supplied to, or desired by, all those in the organisation. It was decided as a result to institute a "circulation service," and at the same time to weed out certain journals, which resulted in reduction of their number from 45 to 15. It was felt that at least three persons—in this case engineers—should show interest in a journal to warrant its inclusion in the circulation service; and that for proper use, no single copy should be routed regularly to more than six engineers. In practice no copy of a monthly was routed to more than five persons.

The article describes in some detail the method adopted of filing back issues, and demonstrates the economy and increased efficiency derived from a rationalised circulation system for technical publications, and the necessity for sufficient copies of issues, so as to ensure adequate time for perusal.

World Power Conference

Short abstracts are given of the papers relating to water power that were presented at the Brazil Sectional Meeting of the World Power Conference.

IN the various World Power Conferences that have been held since 1924 there has been a gradual change of emphasis as the older problems have been solved and newer ones have arisen, and this applies generally and not, of course, alone to the hydro-electrical field. In the 32 papers on water-power matters presented to the 1924 conference, for example, there is no mention of underground power stations, extra high-tension transmission, the co-ordination of generating capacity on an international basis, or any concern about the special design of plants for tropical and sub-tropical areas. On the other hand, there was an interesting paper on the co-existence of hydro-electric and thermal power stations in which the overall economy of production was analysed in relation to water storage and peak loads, and this is a subject which is very much alive today. Indeed, no less than six papers on the joint utilisation of hydro and thermal electric power were presented to the recent conference in Brazil. These relate to what is being done in Sweden—a pioneer in this matter—Brazil, India, Italy, Japan and Great Britain. The second point of emphasis falls on the special requirements in the design of hydro-electric installations in tropical and sub-tropical regions, contributions on this subject emanating from Canadian and French engineers, the latter contributing two.

Among the more diversified papers many deal with specific stations, experience with the international exchange of electrical energy, cast-in-place concrete pipelines, power transmission, telemetering and telecontrol, and so on.

Relation Between Hydro and Thermal Power

Steam Power as a Supplement to Water Power in Sweden. By Folke Petri and Lars Lingstrand. In a country like Sweden, whose power economy is based on hydro-electric schemes, thermal stations make a relatively poor showing, but their rôle is of great importance as it is essentially a multiple one. They function as standby stations in times of water-storage shortages and as basic stations when there is a general shortage of energy; again, they can be used as reserve stations in the event of a breakdown, and can gradually take up additional blocks of load pending the completion of a hydro station which will add a large increment of generating power into the national network. Having regard to the higher capital cost of the hydro station and the cheaper kWh, compared with the reverse position in the thermal station, it is considered that optimum economy is reached when the average water-power resources amount to 110 per cent. of the load. This results in an average supplement of 1 to 2 per cent. from the thermal stations.

Looking into the future, the authors foresee that the water-power resources of Sweden will be fully utilised by 1975, and from this time onwards additional power will have to be obtained from thermal plant. When this point is reached, it will be necessary to make continuous use of steam for basic power, making use of the storage hydro plants to handle the peak loads. It will then be essential to secure the utmost efficiency from the steam stations and to this end the combination of electric generation and heat distribution is being closely studied.

Les Usines Thermiques et la Co-ordination entre Production Hydraulique et Thermique en Italie. Par Mario Mainardis. Hydro-electric development in Italy amounts to about 7,500 MW and thermal power to about 2,050 MW, and it is expected that by the end of 1955 the corresponding figures will be 9,500 MW and 2,500 MW respectively. Italy's hydro-electric resources are about 60 per cent. developed, and assuming an annual increase of 6—7 per cent., development should be complete in about ten years. This situation has involved a radical change in the economics of electricity supply in Italy, and it has become necessary to reorientate the co-ordination of hydraulic and thermal generation. Originally thermal plants were built simply to act as reserves in the event of breakdowns in transmission, but the present policy is to build run-of-river and thermal plants for basic load and to use storage-type hydro-electric stations for peak loads and for frequency regulation. Pumped-storage plants are also in course of development to even out the load curve. The paper gives details of the design desiderata for both thermal and hydraulic stations to meet these requirements.

Thermal Power as a Complement to Hydro-Electric Power in Regions of Large Hydraulic Potential. By George R. Strandberg and James R. Chapman. This paper is directly referable to conditions in Brazil, and the general argument presented is that where stream flow and load variations are such that dependable capacity is limited to that of dry years, the installation of thermal stations can complement the hydro capacity in two ways. In the first place, in addition to augmenting the capacity of the system to meet peak loads it provides a back-up of firm power that justifies the installation of additional low-cost hydro units to utilise average, or better than average, water flows; and in the second place, when the water flow is less than average, the thermal plant can be run at a high capacity factor to support the general input to the system. This complementary feature also makes possible an excess of firm capacity. A description is given of this dual rôle in connection with the São Paulo system; in this the increase in overall capacity as a result of relatively modest additions to the thermal plant is strikingly demonstrated.

A Recent Study on the Joint Utilisation of Hydro and Thermal Power in Japan. By Junji Noda. This study takes into consideration all relevant costs—capital expenditure, coal price related to calorific

value, efficiency of generation, etc.—that enter into the total cost of generating hydro and thermal power, and then deduces which combinations of the two can minimise the overall generating costs in different conditions of stream flow. This is computed on a mathematical basis and it is concluded that the overall generating cost varies in accordance with a value, k, which represents the ratio between the generating power of the hydro system during the season of lowest flow and the maximum power load. This cost is calculated to be a minimum when $k=0{\cdot}3$, and to what extent the issue is affected by introducing water-storage facilities. Assuming the maximum demand to be 100 MW and constant throughout the year, it is established that the combination which would give the minimum generating cost, without pondage, would be 90 MW of hydro plant and 70 MW for thermal. On the other hand, with pondage provided, the ratio would be altered to 90 MW for hydro plant and 40 MW for thermal. In practice, however, as load during the dry season is apt to rise to 110 MW, the 90 MW of hydro plant would have to be supplemented by 50 MW of thermal plant.

Integration of Hydro and Thermal Generation in Great Britain. By J. D. Peattie and A. A. Fulton. In Great Britain, hydro power is of limited significance compared with thermal power so that the conditions obtaining in Sweden and other predominantly hydro-power countries are completely reversed. The generation of hydro power is virtually confined to the Highlands of Scotland and it has been possible, in virtue of the 132 kV grid, to effect a high degree of integration with these plants and the thermal plants in the south of Scotland. Thus it was that in 1952 22 per cent. of the total Scottish output was derived from the hydro stations, which, at the end of that year possessed 510 MW of plant out of a total of 1,668 MW for the whole of Scotland. By 1960 it is expected that the hydro stations will be supplying 30 per cent. of the total energy, or 3,500 million kWh per annum. The latest surveys point to a possible hydro output of 10,000 million kWh per annum and no doubt pumped storage will be developed to meet peak loads. It is considered that the Severn tidal power scheme would result in the saving of a million tons of coal per annum and could easily be integrated with the thermally generated power. Reference is made to the work in progress on the scheme for interconnecting the French and British grid systems by a submarine cable.

Co-ordinated Development of Hydro and Thermal Power Resources in India. By Shri S. A. Gadkary. In this paper the integration of hydro and thermal power is explained with reference to two specific examples—the Damodar Valley Corporation and the Tata Power System. In each case the problem of hydro generation was influenced to a high degree by the monsoon period, which necessitated the construction of storage dams in the hilly portions of the catchment to prevent flood damage and to conserve the runoff for firm power development. In the Damodar Valley scheme, three hydro stations are planned to operate on the base of the load, while a thermal station, equipped wih two 50 MW sets, carries the peaks, which, during this period, do not exceed 100 MW. During the dry season, this plan of operation is reversed; that is, the thermal stations would run at the base of the load curve at full capacity while the hydro stations which are equipped with 120 MW capacity, meet the peaks.

In the Tata system, the total maximum demand is 258 MW, and it is proposed that in dry periods, or in deficient years, the thermal station should operate at the base of the load curve (if necessary throughout the year) while all the available hydro energy is utilised for the peaks. In years of good rainfall hydro power would be used for the base of the load curve during the monsoon period and the peaks met by thermal power.

Particulars are then given of the distribution of the thermal and hydro power resources of India, followed by a discussion of the conditions that govern the extent to which co-ordination bewteen the two is possible.

Influence of Tropical Factors on Design

The Influence of Tropical and Sub-Tropical Factors in the Design of Hydro-Electric Plants. By J. K. Sexton. The author points out that the design of hydro-electric plants intended for tropical and sub-tropical regions is influenced by the necessity to meet high temperatures, extremes of humidity, winds of hurricane force, high floods, and silt-laden streams. Furthermore, power generation has generally to take second place to irrigation so that most large projects have to serve both purposes. The smaller stations, however, are usually designed for power alone and the design can be made simple (there is no freezing problem to contend with) and thus lends itself to automatic operating and remote control. The absence of frost also simplifies the design of dams, intakes, canals, pressure pipes, etc., but other problems are created by excessive floods and the large amounts of silt carried in the water. Underground power stations are stated to be the best means in certain circumstances of protecting the equipment against exceptional floods which may occur in tropical rivers.

Central Thermiques, Aménagements Hydro-electriques, Postes et Lignes en Pays Tropicaux. By B. Level. This paper considers tropical hydro stations from the threefold aspect of the materials to be used, the adaptation of normal-type equipment and the general design of the works. The protection of corrodible materials by electroplating, painting and metallisation is advocated, as, also, is the preferential use of certain insulating materials for the whole of the equipment. A chapter is devoted to the design of alternators with reference to the cooling, insulating and protective methods recommended, and other parts of the survey are extended to the arrangement of the control gear and transformer stations, both of which can advantageously be housed jointly in an air-conditioned room. The final part of the paper deals with transmission lines—the choice of calculation assumptions, the execution of the work, the question of voltage, and the design of transmission towers and their foundations.

Le Rôle de l'energie Électrique dans le Developpment de L'Industrialisation des Pays Tropicaux. By M. de Vertuil. This contribution analyses the trend and characteristics of industry in tropical countries and the rôle which electricity can play, emphasis being placed on low-cost hydro-energy which can be used in conjunction with local products in the electro-metallurgical and electro-chemical industries. Reference is made to the water-power resources of the

Belgian Congo, Rhodesia, the Gold Coast and to various French territories in the tropical belt.

Miscellaneous Papers

Hydro-Electric Power Stations in the Faröe Islands (Denmark). By Stenild Hjorth. This paper describes the climate, population and trades of the islands, and the water-power plant which is being erected near Vestmanna. Initially this plant will consist of a 3,000 h.p. Pelton-driven set designed for a 720 ft. head, but ultimately an additional 5,000 h.p. set will be installed, space for this addition being provided in the present power house. The power will be distributed to some 3,000 households and industrial establishments and will be transmitted over 85 miles of overhead lines. Particulars are given of the financing of the scheme which is being effected partly by Marshall Aid but substantially by the Danish State and various local authorities and savings banks.

Austria's Experiences in International Hydro-Electric Developments. By Dr. Erwin Urban and Dr. techn. Oscar Vas. This interesting paper discusses the work of the Austrian National Committee in solving the various problems which have arisen in connection with the joint utilisation of the water-power resources of streams and rivers which are held in common with neighbouring countries. In order to secure maximum output of kWh per annum, together with efficient generation, the principle of national sovereignty has been largely abandoned and replaced by one which aims at securing the most effective overall development, based on technical and economic considerations alone. In this way it has been possible for the two countries to share catchments and watercourses, to erect dams in each other's territories and generally to take all steps designed to secure optimum output with a maximum of firm power. Various specific schemes are briefly described.

The Electrical Problems Resolved in the system of "Cia. Hidro Elétrica Do São Francisco." By S. B. Griscom and Octavio Marcondes Ferraz. The Paulo Afonso hydro-electric station, Brazil, is situated at some distance from the centres of population—Recife and Salvador—and this paper deals with the analysis made of the system requirements, equipment installed in the power station and receiving substations to ensure an adequate initial supply to these centres and to take care of the future. Network analyser studies indicated that a line voltage of 230 kV would permit the satisfactory operation of transformers using the standard range of taps both for initial requirements and the enhanced loads of the future. In a system of this kind, where the power required for line charging is very large in relation to the connected load, the initial operating conditions are highly critical. A study of the dynamics of the system on a model network established that generators with a short-circuit ratio of 1·98 would have characteristics that would be capable of meeting all the operating conditions in the initial period of light load. Adequate voltage-control is provided at the step-down substations by means of synchronous equipment with automatic voltage regulators, and in order to simplify system operation these synchronous machines are arranged for across-the-line starting as well as for low-voltage starting. Particulars are also given of the earthing system employed, together with other special features which have been incorporated to secure safe and trouble-free operation.

The Design and Construction of Cast-in-Place Concrete Pipe Lines for High Pressures. By R. M. Sedijamo. Concrete pipes are usually cheaper than steel and in normal conditions have greater durability and hence involve lower maintenance costs. The author traces the development of concrete pipes over the last 30 years and speaks of the difficulty of introducing steel reinforcement in view of the fact that concrete has a very limited capacity for taking up tensile stresses. He outlines the conditions which have to be met by the normal type of reinforced-concrete pipe, refers to both American and European practice and then discusses prestressed pipes in relation to the core-tube method of construction and that involving the use of high-grade concrete in conjunction with wires which prestress the pipe wall both longitudinally and circumferentially. He then proposes a new type of concrete penstock which, he suggests, should be lined with a stainless-steel cylinder, 2 mm. to 4 mm. thick, which would ensure watertightness but would be required to take up a very small proportion of the internal pressure. To resist bulk pressure separate bands of ordinary steel, standing 5 cm. away from the lining, would be laid concentrically around the inner pipe and the intervening space then carefully filled in with concrete. The function of this layer of concrete is to transmit and distribute the internal pressure from the internal cylinder to the steel hoops and must therefore be of high quality and free from voids. Finally, to protect the steel rings against corrosion and mechanical damage, a further protecting layer of concrete, at least 3 cm. thick, is laid around the pipe. In a practical test, a pipe constructed in this manner did not break down until a pressure of 880 lb. per sq. in. was reached, equivalent to a static head of 2,000 ft. It is understood that this type of piping is to be used in the construction of Golang water-power station in Java, Indonesia.

Development of Niagara Falls for Hydro-Electric Power, Canada and the United States. By Francis L. Adams. The author describes the physical characteristics of the Niagara river and its place in the St. Lawrence river system, which, including the Great Lakes, has a drainage area of 298,000 sq. miles. Favoured as it is by a concentrated fall of 325 ft. and backed by the unparalleled regulation offered by 95,000 sq. miles of water surface, the Niagara river provides one of the world's best power sites. Early power developments are briefly described and the author then discusses the various international agreements which have from time to time been made to control the regulation and utilisation of these waters, and also to preserve the scenic beauty of the Falls. Particulars are given of the Federal Power Commission's plan for the redevelopment of the river on a co-operative basis by the United States and Canada. By this scheme it is estimated that the installed capacity of the American side could be increased from 445,000 to 1,695,000 kW while the capacity of the Canadian side, now in process of installation, will ultimately be increased by 1,375,000 kW. The total cost, estimated at $17,536,000, is to be divided equally between the two countries.

International Water Problems and Progress made through Treaties, Compacts and Agreements. By W. A. Dexheimer. The author gives a historical sketch of agreements made between neighbouring states in ancient and mediaeval times and then discusses what

has been achieved by the United States in reaching agreement not only with adjacent countries but also within her own borders. He considers that the best procedure for resolving problems is to have agreements drawn up and ratified by legislatures of the states affected and suggests that experience gained within the United States in this respect might very well indicate a possible means of resolving some of the international river problems. To be successful to both parties an agreement should be based on full knowledge of all existing and potential uses of the water involved, and preferably drawn up by a commission headed by a thoroughly competent and disinterested individual. In the United States this office is generally undertaken by a Presidential representative, but of course, in the international field no international agency is yet in being, and this, the author implies, is a deficiency that it would be wise to make good. Among the outstanding international problems awaiting an equitable solution the author cites those of the Nile, the River Plate, the Tigris, the Euphrates, the Jordan, the Yamuk, the Helmand, the Indus and the Ganges. He considers these problems to be pressing in view of the fact that the world's population is increasing at the rate of 70,000 per diem, or 20 million more every year, all needing additional food and power.

Some Technical and Economic Aspects of Power Transmission in Brazil. By Ing. F. P. de Mello. In common with other countries at the present time, the problem of long-distance transmission is receiving an increasing amount of attention in Brazil. This paper is concerned with design considerations directly related to the conditions there and the whole problem is discussed around the economics of alternative schemes which have been worked out for a specific transmission line 200 miles in length. Reference is made to breaking resistors, which have for a number of years been proposed as a means of increasing the stability of a system, but the author considers that more is to be gained through other design improvements involving high-speed relays and the quick clearance of faults. The use of shunt breaking resistors at the dispatch end is regarded as being as effective and economical as the more conventional methods of increasing firm transmission capacity; moreover, these methods have been developed virtually to their limiting values.

L'Usine Hydro Electrique de Paulo Alfonso sur le São Francisco de la "Companhia Hidro Elétrica do São Francisco." By Octavio Marcondes Ferraz. This paper refers to the Paulo Alfonso hydro-electric station, the construction of which represents a first step towards the rehabilitation of a large tract of poverty-stricken terrain in the north-east of Brazil. The plant utilises a head of 80 m. which after regulation measures have been taken, will result in an annual output of 6,000 million kWh. Floods create a problem, and the dam is provided with a spillway capacity of 20,000 cu. m. per sec. For various reasons the power house has been located underground and is at present equipped with three 60,000 kW sets, although six will ultimately be installed. The region is remote, and special care has been taken to provide suitable amenities for the workpeople employed. Transport has proved difficult, as the station is 500 km. from centres in the north and local conveniences were non-existent. Excellent progress has been made, however, and the cost per kW installed will be surprisingly low and the constructional period very reasonable. These excellent results are attributed to sound technical organisation and the atmosphere of goodwill which was created by good labour relations.

La Coupure du Fleuve S. Francisco à L'Usine de Paulo Afonso. By Octavio Marcondes Ferraz and André Blança. This paper describes the method used for erecting a dam across the São Francisco river for the Paulo Afonso power station. At the point chosen for the dam site the river is narrow and deep, the current strong and the bed extremely irregular. These circumstances suggested that special measures should be adopted. To this end a floating caisson, called a "ship," was constructed, anchored from the bank by two cables and sunk in the deepest part of the river where the current was strongest. It was positioned just upstream of the site chosen for the cofferdam and allowed the first half of this to be constructed without further difficulty. Within this cofferdam the first half of the sluiceway dam was completed. The midstream portion of the cofferdam was retained while the remainder was demolished to allow as much flow as possible to pass through the sluice gate. Even so the current in the second half of the river was too strong (6 m. per sec.) to permit a cofferdam to be erected. To meet this difficulty a structural steel barrier was constructed, built in two sections which were sufficiently light to be handled by derrick cranes. The girder work of these sections was lined with 25 cm. steel meshing on the downstream side. After they had been lowered into position they were filled to the required degree with 30 cm. pebbles to slow down the current sufficiently to enable the erection of the second half of the cofferdam to proceed. It is concluded that the "floating caisson" and the "semi-flexible" steel barrier can be used with great advantage in working in deep turbulent rivers.

Association de Groupes Anémo-Éléctriques avec les Usines Hydro-Éléctriques Régularisées. By H. Duguennois. The author discusses the operation of wind-power units running in conjunction with hydro units, with special reference to the conditions obtaining in Algeria. The optimum results are secured by combining the two sources of power when the seasonal winds reach their maximum intensity during the period of low runoff. In Algeria, the author considers that batteries of wind generators would greatly reduce the serious dearth of energy which occurs in very dry years and would help appreciably in postponing the date at which capacity losses in the storage reservoirs of the hydro-electric plants would have to be restored by an expensive cleaning operation. An economic analysis suggests that in this particular case a capital expenditure of 70,000 fr. (about £70) per kW installed would be justified, and trusts that this conclusion will encourage inventors to design wind generators that will be reliable in service and cheap to maintain.

Principios Tecnicos y Económicos del Aprovechamiento Internacional de las Angas del Lago Titicaca. By Prof. Ing. Reinaldo Harnecker, Prof. Ing. Renato Salaza and Ing. Domingo Santa María. In this paper the authors discuss a proposal to make use of the waters of Lake Titicaca (elevation 3,800 m.) for power development, and possibly irrigation. By placing the power station on the Atlantic side of the Andes it would be possible to develop an ultimate

(Continued on page 390)

Fig. 1. Aerial view of Pole Hill penstock and power plant

High-Head Penstocks in the Rockies - I

Design and construction features of the penstocks for the Pole Hill and Flatiron power plants of the Colorado-Big Thompson project.

By PETER J. BIER*

THE ever-increasing demand for more power accelerates the development of our remaining hydraulic power resources at a much faster rate than anticipated but a few years ago. In semi-arid regions, where hydro-electric power is generally a byproduct of irrigation, this power plays an important rôle in the overall economy of the area. Many irrigation projects are economically feasible only because of the revenue derived from the sale of the hydro-electric power developed with stored water. Where water and irrigable land are separated by mountains, it may be feasible to bring them together by means of transmountain diversion. This has been accomplished on the Colorado-Big Thompson project. Here water originating on the western slope of the Continental Divide is conveyed to the eastern slope through a 13-mile long transmountain diversion tunnel. This diverted water supplements the inadequate irrigation supply for 700,000 acres of rich farm land along the South Platte River and tributaries. The idea of this transmountain diversion dates back to the year of 1889. After the feasibility of the scheme had been determined by detailed surveys and investigations, the Colorado-Big Thompson project

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was authorised by the Congress in 1937. Construction, however, could not be started without a contract between the water users and the United States. Consequently, the Northern Colorado Water Conservancy District was organised which included areas from eight counties. Construction work was started with Green Mountain dam and power plant and contracts followed for other features at regular intervals.

On its course to the thirsty land the water is run through the turbines of several power plants before it is released for irrigation. These include the Marys Lake, Estes, Pole Hill, and Flatiron plants. The two last named have been completed only recently and are the subject of this article. Both are high-head plants utilising the water diverted through the transmountain, or Alva B. Adams tunnel.

The Colorado–Big Thompson project is one of the most interesting and diversified schemes ever undertaken by the Bureau of Reclamation. Its principal features are located in an area known for its scenic attractions, being in the vicinity of Rocky Mountain National Park. Water from the Colorado river is stored in Granby reservoir which was formed by the construction of Granby dam. From this reservoir, the water is pumped by means of three electric-driven centrifugal pumps of the Granby pumping plant into Shadow Mountain lake which was created by the construction of Shadow Mountain dam. This reservoir is connected with the scenic Grand Lake, from which the water is conveyed through the transmountain diversion tunnel to the eastern slope. On the eastern slope the water flows through Aspen Creek syphon and Rams Horn tunnel to a penstock serving the Marys Lake power plant. The tailwater from this plant runs into Marys lake formed by a dyke. From here the water flows through the Prospect Mountain conduit and tunnel to the three penstocks serving the Estes power plant. The tail water from the Estes plant flows into Lake Estes, which was formed by the construction of Olympus dam. This lake supplies the water to the

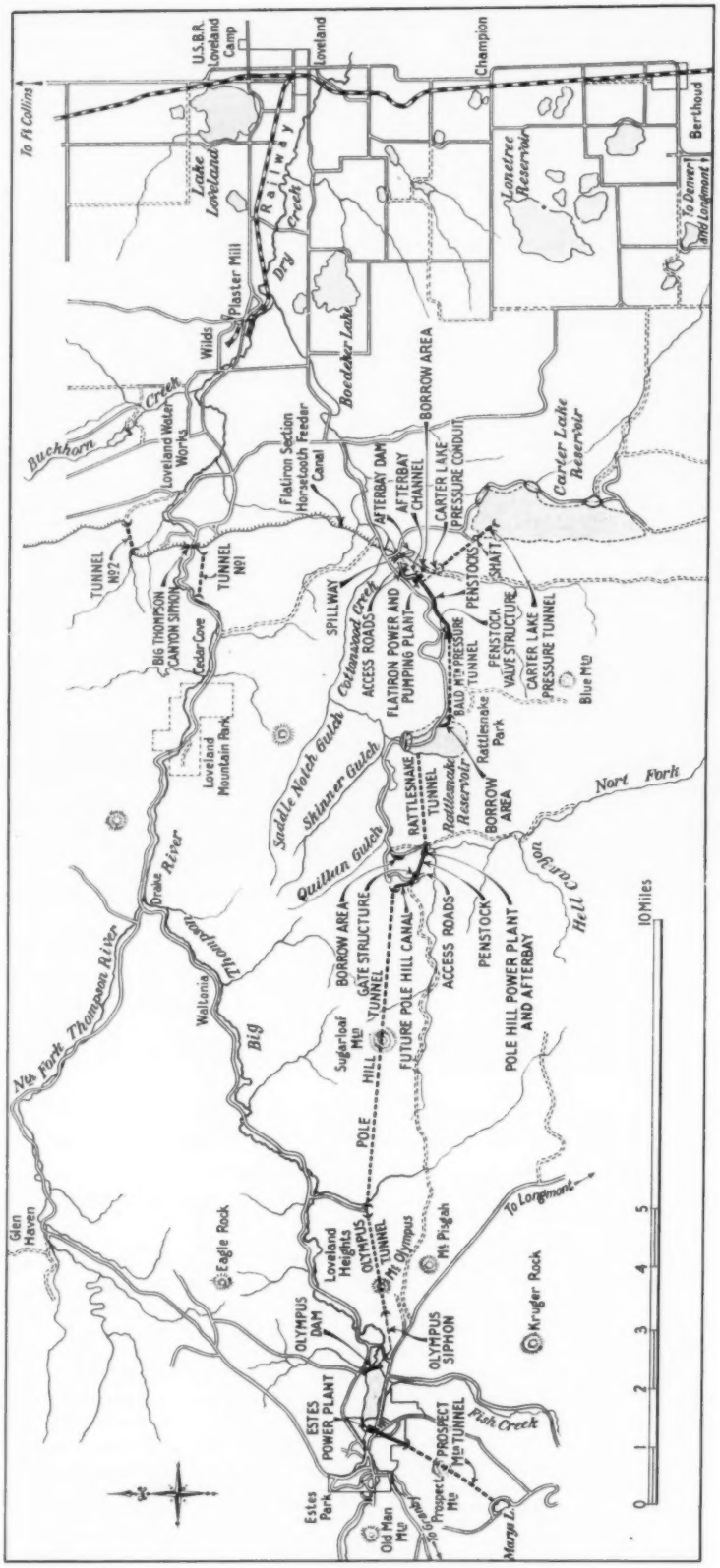


Fig. 2. Location map showing power plants

Fig. 3. Aerial view of Flatiron penstocks and power plant

Pole Hill penstock and power plant. First the water flows through Olympus syphon and tunnel, then through the Pole Hill tunnel and canal before entering the penstock. Tailwater from the Pole Hill turbine flows through Rattlesnake tunnel into Rattlesnake reservoir. This reservoir supplies the water to the two Flatiron penstocks by means of the Bald Mountain pressure tunnel. A portion of the water is pumped through a pressure conduit and tunnel into Carter Lake reservoir serving irrigation requirements. The remainder of the water flows into a reservoir formed by the Afterbay dam. From this reservoir, the water runs into Dry Creek and the Big Thompson river.

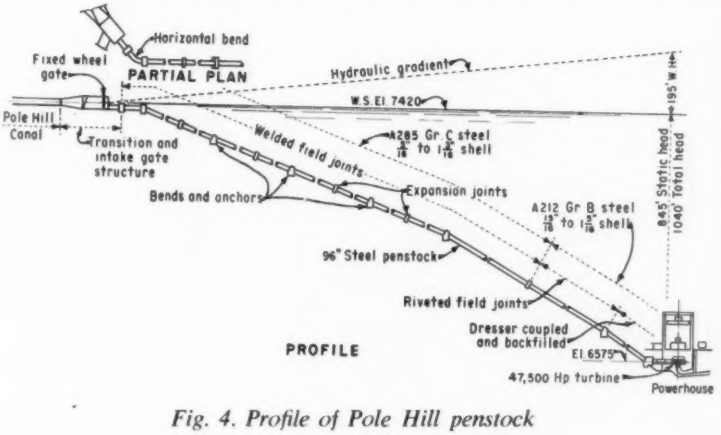
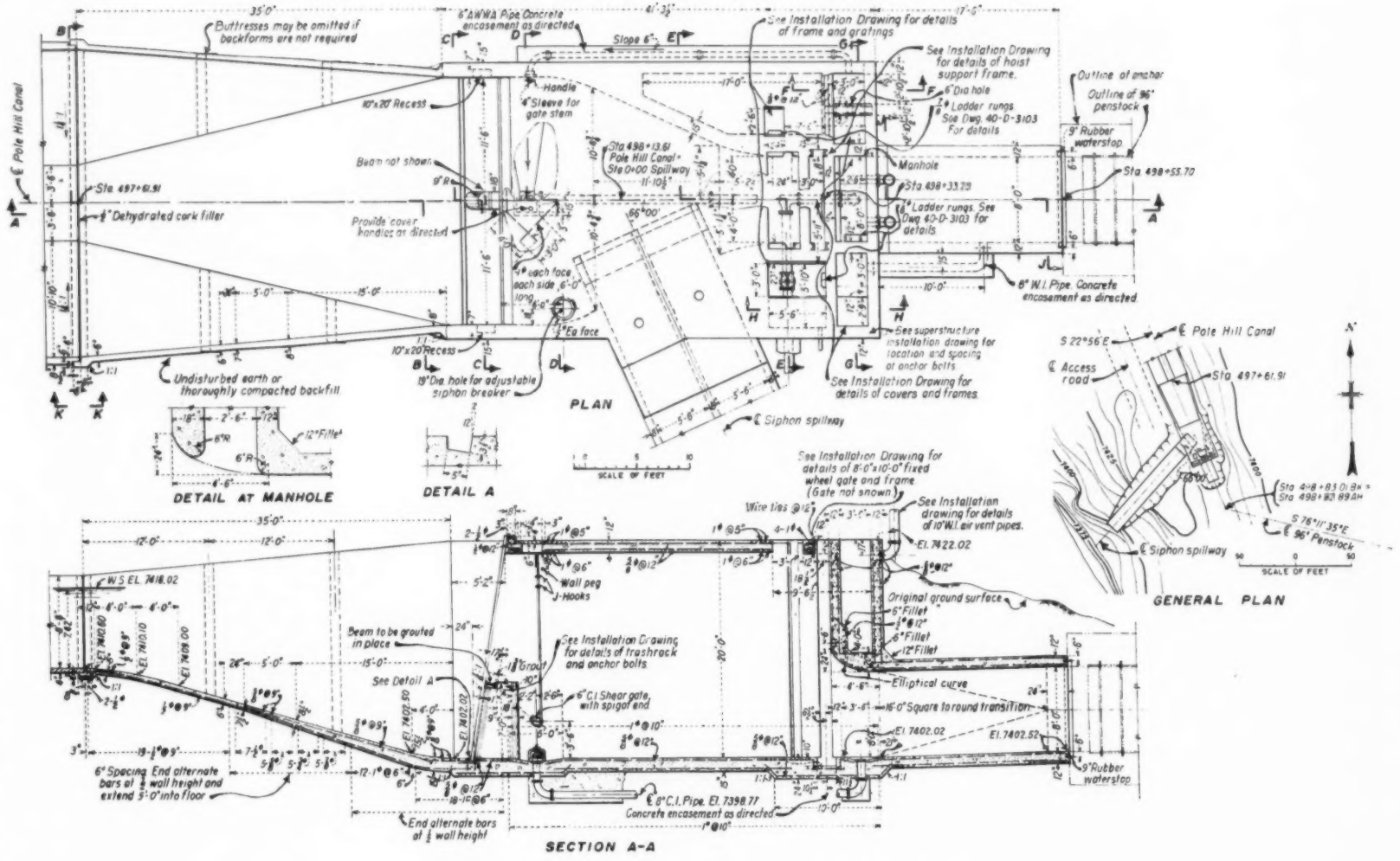


Fig. 4. Profile of Pole Hill penstock

Both power plants are located in the foothills area south-west of Loveland, Colorado. The Pole plant is about 16 miles south-west of Loveland and 10 miles east of Estes Park, while the Flatiron plant is located about five miles east of the Pole Hill plant. Both plants are accessible over gravel-surfaced construction roads branching off the paved highway leading to Estes Park and Rocky Mountain National Park. Fig. 2 shows a location map of the dams, tunnels, power plants, penstocks, and other project features.

Description of Power Plants

The Pole Hill and Flatiron power plants have a combined


PLAN
DETAIL AT MANHOLE
DETAIL A
GENERAL PLAN
SECTION A-A
Pole Hill Canal
Buttresses may be omitted if backforms are not required
6" AWWA Pipe Concrete encasement as directed
Slope 6"
See Installation Drawing for details of frame and gratings
See Installation Drawing for details of hoist support frame.
Outline of anchor
Outline of 96" penstock
9" Rubber waterstop
Handle
4" Sleeve for gate stem
10"x20" Recess
Sta 498+13.61 Pole Hill Canal Sta 0+00 Spillway
Sta 498+55.70
Manhole
Sta 498+33.23
Ladder rungs See Dwg 40-D-3103 for details
Beam not shown
Sta. 497+61.91
½" Dehydrated cork filler
Provide cover handles as directed
each face each side
6" W.I. Pipe. Concrete encasement as directed
See superstructure installation drawing for location and spacing of anchor bolts
See Installation Drawing for details of covers and frames.
Undisturbed earth or thoroughly compacted backfill
15" Dia. hole for adjustable siphon breaker
Siphon spillway
See Installation Drawing for details of 8'-0"x10'-0" fixed wheel gate and frame (Gate not shown)
See Installation drawing for details of 10" W.I. air vent pipes.
El. 7422.02
Wire ties @12"
Wall peg J-Hooks
W.S. EL. 7418.02
Original ground surface
6" Fillet
6" Fillet
12" Fillet
Beam to be grouted in place
See Installation Drawing for details of trashrack and anchor bolts
See Detail A
Grout
6" C.I. Shear gate, with spigot end
Elliptical curve
16'-0" Square to round transition
El. 7402.02
El. 7402.52
9" Rubber waterstop
6" Spacing End alternate bars of ½ wall height and extend 5'-0" into floor
End alternate bars of ½ wall height
8" C.I. Pipe. El. 7398.77 Concrete encasement as directed
S 22°56' E
Access road
Sta 497+61.91
Sta 498+83.01 Sta 498+83.89
S 76°11'35" E
96" Penstock
Siphon spillway
SCALE OF FEET
N

HIGH-HEAD PENSTOCKS IN THE ROCKIES

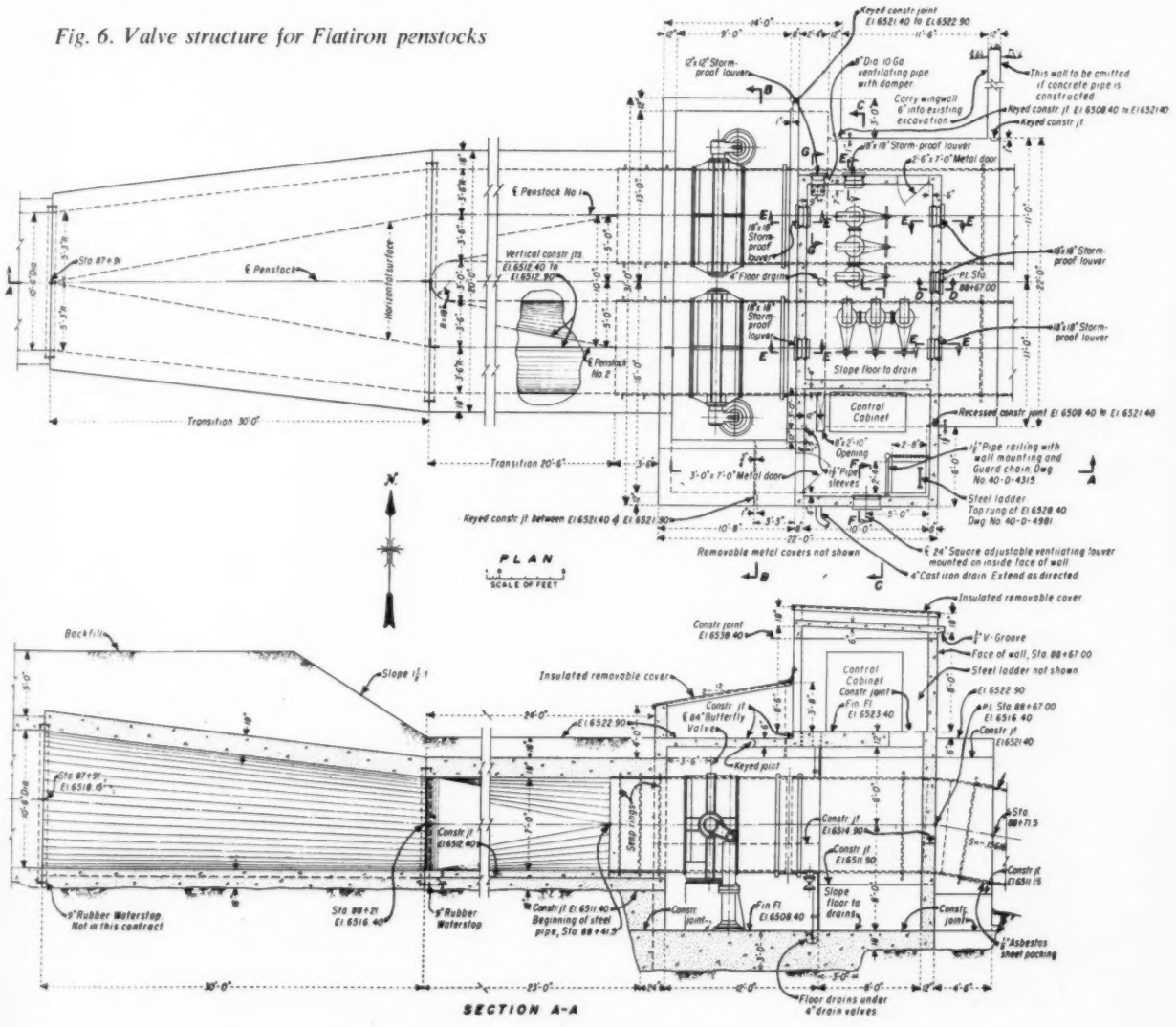
Fig. 5. Intake structure for Pole Hill penstock

capacity of 104,750 kW and furnish continuous power to the Government's interconnected power system in northern Colorada, Wyoming, and Western Nebraska. The Pole Hill plant and unit No. 1 of the Flatiron plant were placed in operation during January 1954. Unit No. 2 of the Flatiron plant was put on the line in May 1954. The power plants are of heavy reinforced-concrete construction. Each turbine is provided with a pressure regulator and energy absorber. The Flatiron plant is, in addition, provided with a 50 ft. diameter reinforced-concrete surge tank to improve speed regulation of the turbines. The surge tank is located at the outlet portal of the Bald Mountain pressure tunnel.

The Pole Hill power plant has one vertical-shaft single-runner Francis-type turbine rated at 47,500 h.p. at full gate opening, when operating at 450 r.p.m. under an effective head of 815 ft. This turbine drives a 35,000 kVA 0·95 power-factor generator. Utilisation is made of the regulated flow from the Estes plant through Lake Estes. The turbine is installed at elevation 6,575 above sea level and all apparatus was designed for operation at this altitude. Tailwater passes through a small afterbay to Rattlesnake tunnel, which discharges into Rattlesnake reservoir. Fig. 2 shows an aerial view of the Pole Hill penstock and power plant.

In the Flatiron power and pumping plant, two vertical-shaft single-runner Francis-type turbines, and a turbine-type centrifugal pump are installed. Each turbine is rated at 48,000 h.p. at full gate opening, when operating at 514 r.p.m. under an effective head of 1,045 ft. The turbines are connected to 35,000 kVA, 0·90 power-factor generators. In this plant utilisation is made of the regulated flow from Pole Hill power plant through Rattlesnake reservoir. The turbines are installed at elevation 5,457 above sea level. The pump-turbine unit will be used for pumped-storage operation to pump water from the afterbay of the Flatiron plant to Carter Lake reservoir. This pumped water will be stored in Carter lake for release as required. A portion of the water

Fig. 6. Valve structure for Flatiron penstocks


PLAN
SCALE OF FEET
SECTION A-A
Transition 30'0"
Transition 20'6"
℄ Penstock
℄ Penstock No 1
℄ Penstock No 2
Vertical constr jts El 6512.90
Horizontal surface
Sta 87+91
Keyed constr joint El 6521.40 to El 6522.90
12'x12' Storm-proof louver
8" Dia 10 Ga ventilating pipe with damper
This wall to be omitted if concrete pipe is constructed
Carry wingwall 6" into existing excavation
Keyed constr jt El 6508.40 to El 6521.40
Keyed constr jt
8'x18' Storm-proof louver
2'-6"x7'-0" Metal door
18'x18' Storm-proof louver
4" Floor drain
Pl Sta 88+67.00
Slope floor to drain
Control Cabinet
Recessed constr joint El 6508.40 to El 6521.40
8'x2'-10" Opening
2'-8"
1½" Pipe railing with wall mounting and Guard chain Dwg No. 40-D-4319
3'-0"x7'-0" Metal door
1½" Pipe sleeves
Steel ladder Top rung of El 6528.40 Dwg No. 40-D-4981
Keyed constr jt between El 6521.40 & El 6521.90
Removable metal covers not shown
℄ 24" Square adjustable ventilating louver mounted on inside face of wall
4" Cast iron drain. Extend as directed
Backfill
Slope 1½:1
Insulated removable cover
Constr joint El 6538.40
1" V-Groove
Face of wall, Sta 88+67.00
Steel ladder not shown
Control Cabinet Constr joint Fin Fl El 6523.40
El 6522.90
Pl Sta 88+67.00 El 6516.40
Constr jt El 6521.40
24'-0"
℄ 84" Butterfly Valve
Constr jt
Keyed joint
Sta 87+91 El 6518.15
Constr jt El 6514.90
Constr jt El 6511.90
Constr jt El 6511.15
Sta 88+71.5
Step rings
Constr jt El 6502.40
9" Rubber Waterstop Not in this contract
Sta 88+21 El 6516.40
5" Rubber Waterstop
Constr jt El 6511.40 Beginning of steel pipe, Sta 88+41.5
Constr joint
Fin Fl El 6508.40
Slope floor to drains
Constr joint
½" Asbestos sheet packing
Floor drains under 4" drain valves

will be returned through the pump-turbine to generate power or will be bypassed around it when required to supplement the discharge from the main turbines, and to provide the required irrigation water discharging from the afterbay of the plant into the Horsetooth feeder canal. When operating as a turbine, the unit has a capacity of approximately 9,200 h.p. under an effective head of 250 ft. As a pump it operates under heads of 170 to 300 ft., with a minimum capacity of 250 cusec. and is driven with a 13,000 h.p. electric motor. Fig. 3 shows an aerial view of the Flatiron penstocks and power plant.

General Features of Pole Hill Penstock

A single penstock serving the Pole Hill plant is connected to the Pole Hill canal by means of an intake-gate structure. The penstock is installed on a steep hillside with slopes varying from 21° at the upstream end, to 34° at the downstream end. It has an inside diameter of 96 in. which is reduced by means of a reducing bend to 60 in. diameter at the downstream end near the turbine. The overall length of the penstock is 2,040 ft. Fig. 4 shows a profile of the penstock, which consists of eight tangent sections of varying slopes connected with vertical bends encased in reinforced-concrete anchors. The only horizontal bend is in the short upstream section between anchors Nos. 1 and 2, which was backfilled with earth. This bend was provided with a make-up joint having an outside butt strap, which was to be left unwelded during installation to permit free temperature movements while the penstock was exposed and subjected to great temperature variations. All other tangent sections, except one between anchors Nos. 7 and 8, have been provided with expansion joints between anchors to accommodate temperature changes in the line. The short 60 in. diameter downstream end section was equipped with a flange for connection to the turbine scrollcase. A Dresser coupling was installed in this end section near the flange to permit adjustments between penstock and scrollcase flanges and assure a watertight bolted connection. The gate structure at the upstream end of the penstock is of reinforced-concrete construction as shown in Fig. 5. It was designed as a transition between the Pole Hill canal and the penstock, and includes the gate structure with trashrack and an 8 ft. by 10½ ft. fixed-wheel gate for controlling the flow into the penstock. This gate will also be used with a partial opening for filling the penstock. A syphon spillway connected to the gate structure will spill the water during gate closure. The upstream end of the penstock is provided with two seal rings to assure effective anchorage and a watertight connection with concrete anchor No. 1. This anchor was placed against the short concrete pipe at the downstream end of the gate structure, being connected to it with a rubber waterstop which was embedded in the two adjoining concrete structures.

The Pole Hill penstock was installed above the ground surface with the exception of the tangent section at the downstream end, between anchors Nos. 7 and 8, which was backfilled with earth after erection, testing, and exterior coating. Dresser-type sleeve couplings were used for the five field girth joints of the buried section of the penstock. For the upstream portion of the penstock, about 1,500 ft. in length, A285, Grade C steel was used, and for the lower, high-head portion, A212 Grade B steel. The field joints of sections of the penstock fabricated from A285 Grade C steel were butt welded, and the field joints of the exposed sections fabricated from A212 Grade B steel were butt riveted.

General Features of Flatiron Penstocks

The two penstocks serving the Flatiron plant are connected to the Bald Mountain pressure tunnel which carries water from Rattlesnake reservoir to

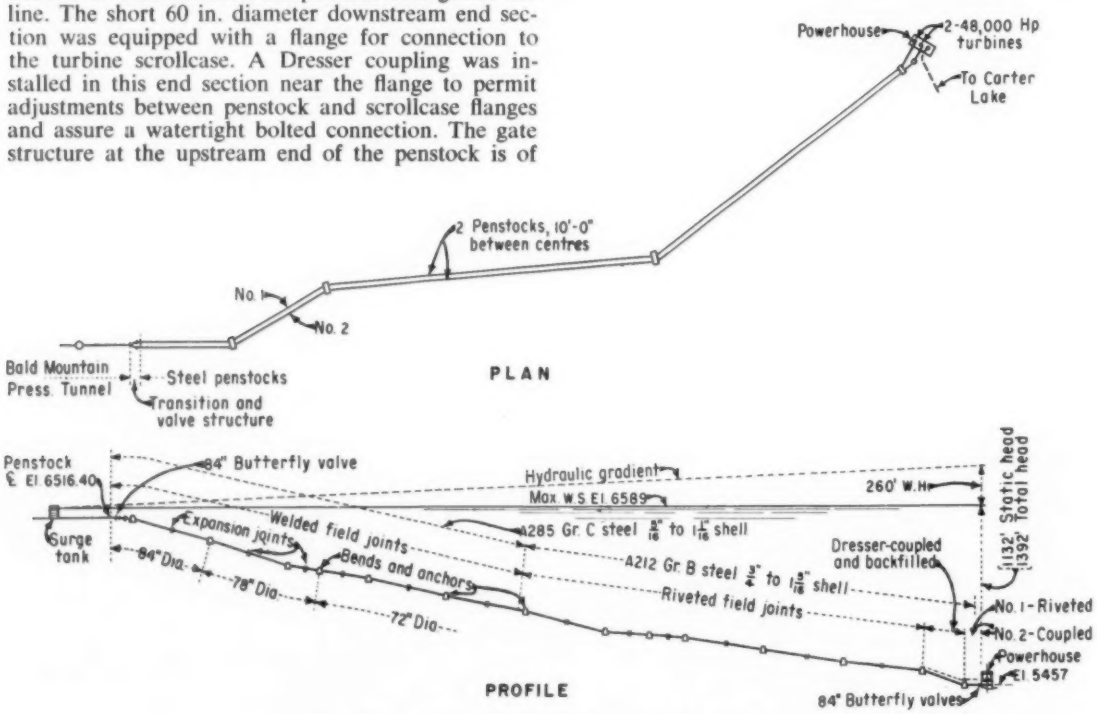


Fig. 7. Profile and plan of Flatiron penstocks

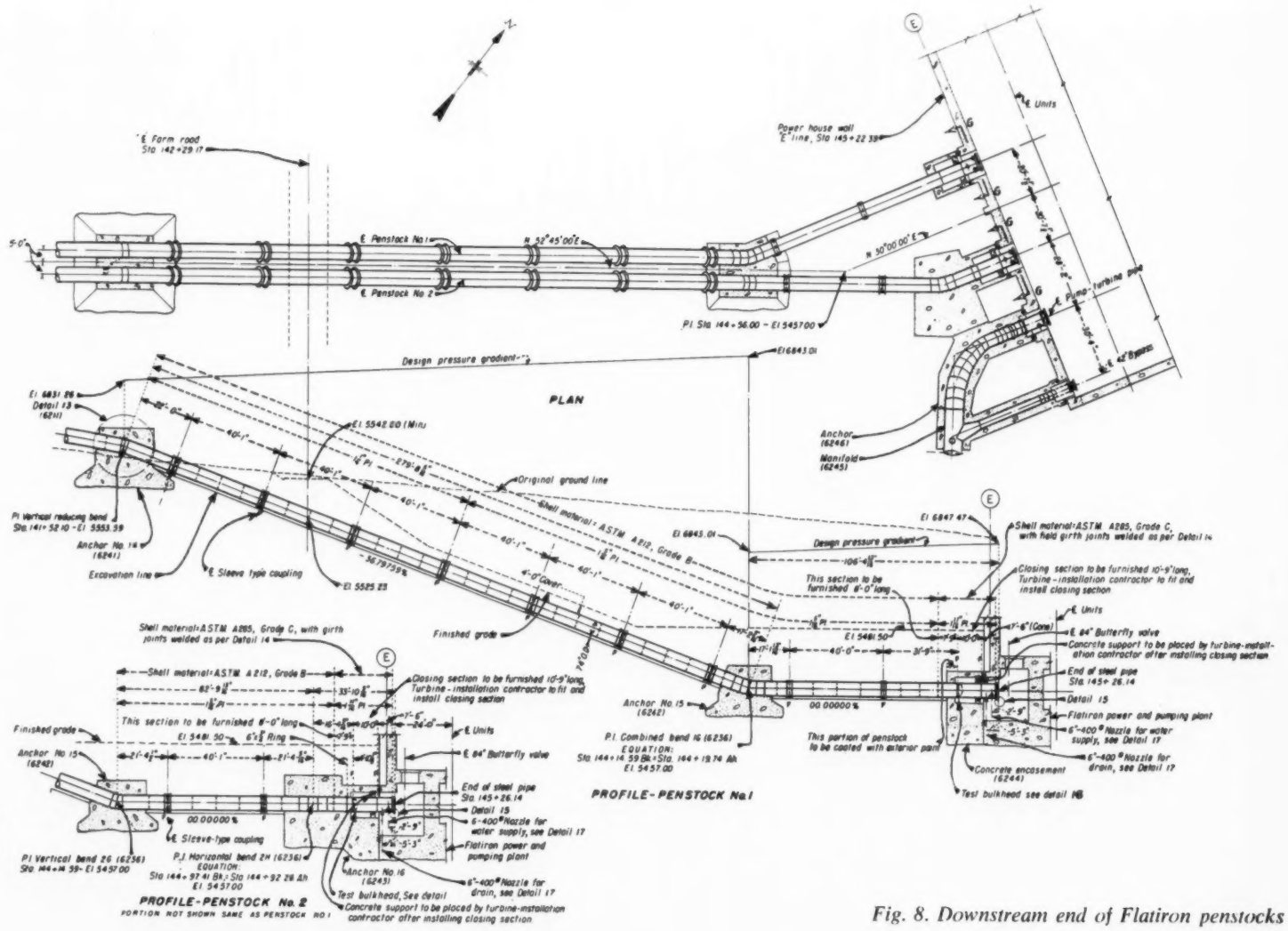

PLAN
PROFILE-PENSTOCK No.1
PROFILE-PENSTOCK No.2
℄ Penstock No.1
℄ Penstock No.2
℄ Units
Power house wall
Anchor (6246)
Manifold (6245)
Anchor No.15 (6242)
Anchor No.16 (6243)
Anchor No.18 (6241)
℄ Sleeve type coupling
℄ Sleeve-type coupling
Original ground line
Finished grade
Excavation line
Design pressure gradient
Shell material: ASTM A212, Grade B
Shell material: ASTM A285, Grade C, with girth joints welded as per Detail 14
Closing section to be furnished 10'-9" long, Turbine-installation contractor to fit and install closing section
This section to be furnished 8'-0" long
℄ 84" Butterfly valve
End of steel pipe Sta 145+26.14
Detail 15
Flatiron power and pumping plant
6"-400# Nozzle for water supply, see Detail 17
6"-400# Nozzle for drain, see Detail 17
Concrete encasement (6244)
Test bulkhead see detail 16
Concrete support to be placed by turbine-installation contractor after installing closing section
This portion of penstock to be coated with exterior paint
P.I. Sta 144+56.00 - El 5457.00
P.I. Combined bend 16 (6236) EQUATION: Sta 144+14.59 Bk = Sta 144+19.74 Ah El 5457.00
P.I. Vertical bend 26 (6236) Sta 144+14.59 - El 5457.00
P.I. Horizontal bend 2H (6236) EQUATION: Sta 144+97.41 Bk = Sta 144+92.26 Ah El 5457.00
P.I. Vertical reducing bend Sta 141+52.10 - El 5553.39
Pi Vertical reducing bend Sta 141+52.10 - El 5553.39
Detail 13 (6211)
El 6831.86
El 6843.01
El 6847.47
El 5542.00 (Min.)
El 5525.23
El 5481.50
N 32°45'00"E
N 30°00'00"E
5'-0"
Shell material: ASTM A285, Grade C, with girth joints welded as per Detail 14

Fig. 8. Downstream end of Flatiron penstocks

the penstock intake. Stoplogs installed in the intake structure to the tunnel can be used as an emergency shut-off to unwater the tunnel, surge tank, and the penstocks when required for inspection and maintenance. The penstocks were designed with variable diameters ranging from 84 in. at the upstream end, to 78 in. at anchor No. 3, and 72 in. at anchor No. 5. This variable-diameter design was determined by an economic analysis. The flow into each penstock will be controlled with an 84 in. butterfly valve at the upstream end of the line. A similar valve controls the flow into the turbine at the downstream end of each penstock. Three 10 in. automatic air-inlet valves were provided for each penstock, located downstream from the butterfly valves to admit air when draining the penstock and so prevent subnormal pressures inside the pipe. Each air inlet is protected with a shut-off valve to facilitate maintenance of the air valve. Fig. 6 shows the penstock valve structure, which is of reinforced-concrete construction. Its upstream end was placed against the 10½ ft. diameter Bald Mountain pressure tunnel, being connected to it by means of a rubber water-stop embedded in adjoining concrete structures. Beginning at this point the valve structure is formed as a transition from the 10½ ft. diameter tunnel cross section to two 7 ft. diameter conduits leading to the butterfly valves. The steel penstocks start 8 ft. upstream from the centres of the butterfly valves, with the upstream ends encased in concrete. A watertight connection with the concrete encasement was provided by three seep rings welded to the encased end of each penstock. Installation of the butterfly valves was facilitated by providing flanges at the ends of adjoining pipe sections. Dresser couplings in the pipe sections downstream from the butterfly valves provided the required flexibility for the installation of the valves and will facilitate valve removal when necessary.

Penstock No. 1 has an overall length of 5,790 ft. and penstock No. 2 5,796 ft. The two penstocks were placed parallel with a spacing of 10 ft. between centres, except at the downstream end near the power plant, where they have been spread out to accommodate a turbine spacing of 41 ft. 3 in. Fig. 7 shows the profile and plan of the Flatiron penstocks and Fig. 8 shows the downstream ends of the penstocks entering the power house.

The Flatiron penstocks run downhill on a slope varying from about 5° to 20°. They consist of a number of tangent sections with bends between tangents. The bends, except four in each penstock, are vertical bends and all are encased in reinforced-concrete anchors. Expansion joints were provided between anchors of all exposed tangent sections.

The Flatiron penstocks were installed above the ground surface except the two downstream tangents below anchor No. 14, which were backfilled after erection, testing and coating. For the upstream portions of each penstock, comprising about 2,720 ft. in length, A285 Grade C steel was used, and A212 Grade B steel for the remainder of each line. The field girth joints of the penstock sections made from A285 steel were butt welded and those made from A212 steel were butt riveted, except the downstream end sections which were mostly Dresser-coupled.

(To be continued)

From page 382

capacity of 1,900 MW and an annual output of 17 million kWh. The possibility of using such a large block of power they consider to be remote, and they consequently favour the diversion of the water to the Pacific coast. Here the water would be in much demand for power, irrigation and industrial and domestic uses. To secure this end the water would have to be pumped in stages up to an elevation of 4,100 m. but a good deal of this energy would be required in the generation of energy in hydro stations which are estimated to have a capacity of 1,700 MW and to be capable of generating 18,000 million kWh per annum. This energy could be comfortably absorbed by mining interests.

This project is of considerable magnitude, and the author advocates that the countries concerned—Chile, Peru and Bolivia—should make a joint survey of the possibilities and further recommend that an International Technical Commission should be appointed and entrusted with this work.

O Aproveitamento Hidroeléctrico do Douro International. By Pedro A. Nunes. This paper outlines the arrangements which have been made between the authorities of Spain and Portugal so that each country shall enjoy an equitable share of the waters of the Douro river. For this purpose the international reach has been divided into two parts, corresponding approximately to the same total fall, the upstream portion having been granted to Portugal and the lower to Spain. The main stipulations in the agreement—which might well serve as a model for other agreements of the kind—(a) forbid the diversion of the stream flow (even during floods) into lateral basins; (b) forbid any irregularity in the working of a power plant in the Portuguese portion operating to the detriment of the plants in the Spanish section by creating an exceptional backwater level; (c) similar limitations are placed on the Portuguese stations in that are prohibited to regulate the flow in such a way as to operate to the detriment of the downstream Spanish stations; (d) the limits allocated to each country are defined in terms of fall, taking into consideration tailrace levels, etc.; (e) each country is allowed to encroach beyond the territorial limits defined by the axis of the river if this course can be shown to be expedient.

Téléphonie, Télémesure et Télécommande dans les Reseaux Haute Tension. By Ing. Hermann Neugebauer, Ing. Heinrich Karl Podzeck and Ing. Karl Schönhammer. A quick and sure means of intercommunication is becoming more and more necessary as power networks become more extended. Reference is made to telephone and teleprinters and to the growing tendency to utilise telemetering, telecounting and remote control facilities for the supervision and control of distribution systems. A warning is given about the danger inherent in placing low-voltage communicating lines in proximity to high-tension power lines.

Reference is also made to using the power lines themselves for communication services, with carrier freqencies ranging from 50 to 300 kc/s. Radio is also capable of taking its place, either as linkages between fixed stations or as non directional transmitters to convey messages to breakdown gangs or other scattered personnel.

The Gal Oya Development

One of Ceylon's major multiple-purpose developments is described by S. M. Alexander, Civil Engineer, International Engineering Company.

PART TWO

Intake, Conduit and Outlets

Intake.—At the upstream toe of the main dam near the left abutment a 162·5 ft. high tower of reinforced concrete serves as the intake structure to a 13 ft. internal-diameter conduit which supplies water for power and irrigation (Fig. 6). A 52 ft. high semi-circular trashrack structure is located at the base of the tower. The maximum velocity through the gross area of the racks will be 2 ft. per sec. No provision was made for mechanical raking since the pool will be drawn down below the top of the racks at elevation 200 at least once annually, permitting access for hand cleaning. The concrete frame of the rack structure as well as the entire tower below the maximum reservoir level are designed to withstand stresses caused by an external head of 20 ft. resulting from possible hydraulic losses at the racks. The welded steel racks themselves are designed to fail under the same head so that excessive clogging at the racks will not damage the more expensive concrete frame. The tower section is a 25 ft. diameter octagon (Fig. 7) designed to withstand stresses produced by (1) A horizontal acceleration of 0·05*g* due to earthquake with a full reservoir, or (2) A wind load of 30 lb. per sq. ft. with the reservoir drawn down. It must also resist uplift forces. Closure at the upstream end of the conduit is effected by an 11 × 13·33 ft. fixed-wheel gate weighing approximately 28,600 lb. The gate is controlled by an electrically operated hoist with a rated capacity of 65 tons provided with a fan brake for emergency lowering. The hoist is enclosed in a house atop the tower. A structural-steel footbridge connects the tower to the top of the dam. This consists of five pairs of simply supported 36 in. wide flange sections set on concrete piers spaced at 79 ft. 4 in. and founded on the slope of the dam.

Conduit.—The conduit is a 13 ft. internal diameter welded steel pipe with a reinforced-concrete envelope. The conduit is set in a trench excavated in solid rock in the foundation of the dam at the left abutment. It is designed to withstand stresses caused by internal loading when full and external soil and water pressure when empty. The pipe was shop welded of $\frac{7}{16}$ in. steel plate into 30 ft. sections. The sections, braced by timber spiders, were set on concrete pedestals in the rock trench, levelled by an adjustable nut and aligned horizontally by screw jacks (Fig. 8). Concrete encasement for a length of 23 ft. 6 in. of each section was then poured and allowed to set for 10 days before the girth joints were welded. The encasement was then poured around the girth joints and the conduit invert grouted using a pressure of 10 lb. per sq. in. Three-foot wide, 18 in. thick concrete collars were placed around the envelope of the seven central conduit sections to minimise seepage along the conduit. Overall length of the conduit is 781·5 ft.

Near the end of the conduit is a 48 ft. restricted-orifice surge tank of $\frac{11}{16}$ to $\frac{3}{8}$ in. welded steel plate with an overall height of 112 ft. The top of the tank is at elevation 279·5, 19·5 ft. above the maximum power pool. The tank is supported on a concrete base with the contact between the steel baseplate and the concrete grouted with a pressure of 10 lb. per sq. in. to obtain uniform bearing.

The conduit terminates at a concrete-embedded steel manifold section from which two 6 ft. branch pipes take off to the irrigation bay of the power house, and four 6 ft. 6 in. branch pipes to the unit bays. The two upstream unit branches are sealed by steel bulkheads pending future installation of additional units.

The irrigation outlets located in the irrigation bay of the power house are regulated by two 66 in. fixed dispersion-cone (Howell-Bunger) valves which are electrically operated. Emergency shut-off immediately upstream is effected by hand-operated 72 in. Dow valves, and there is provision for stoplogs downstream to unwater the irrigation bay. Each valve has a rated capacity of 1,100 cusecs at a net head of 50 ft. A 12 ton rail-hugger monorail chain hoist was installed for the erection and servicing of all four valves. Spray from the valves is localised by a reinforced-concrete hood structure lined with steel plate.

Power Plant

The power house has an overall length of 169 ft., a width of 83 ft. and a maximum height of about 70 ft. above the foundation. It consists of four 25 ft. unit bays, a 26 ft. irrigation outlet bay and a 43 ft. service bay. A cross section of the power house is shown in

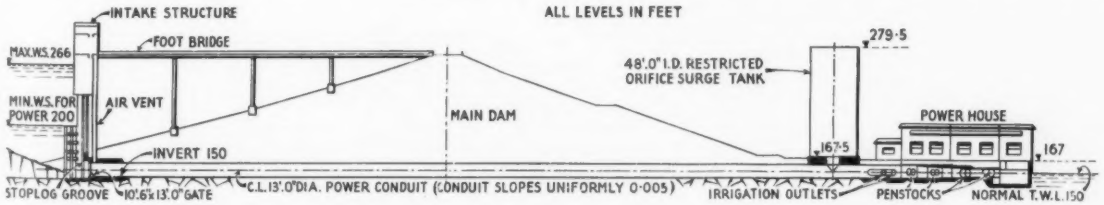


Fig. 6. Cross section through intake and conduits

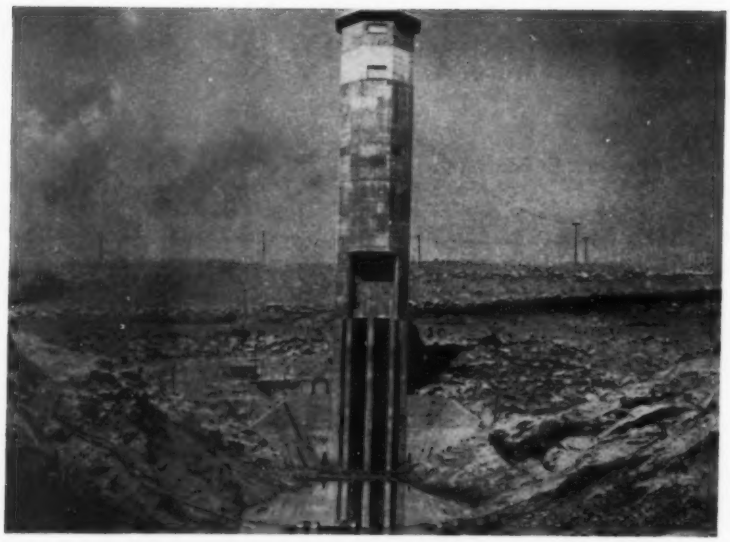


Fig. 7. Intake approach channel before diversion

Fig. 8. Construction of power conduit

Fig. 11. The substructure is concrete, while the superstructure consists of a steel framework having exterior curtain walls of rubble masonry, stuccoed on the outside and plastered on the inside. Exterior architectural treatment conforms more or less with traditional Ceylonese practice (Fig. 10).

An overhead electrically operated travelling crane is installed with a 20 ton capacity main hoist and a 5 ton auxiliary hoist. The power house is ventilated throughout by a forced-draught system. An automatic telephone exchange provides an internal communication system connected with the system in the operator's village.

Turbines.—Two vertical-shaft Francis wheels with steel spiral cases are installed. They are rated at 3,300 h.p. when operating at a net effective head of 89 ft. and at a speed of 333·3 r.p.m. The centreline of the units is at elevation 153 and normal tailwater at elevation 150, thus providing a normal maximum head of 110 ft. Minimum operating head is 50 ft. Speed is regulated by two Woodward governors sensitive to variations of one-sixteenth of one per cent. and adjusted to a closure time of three seconds. The flyball mechanism is operated from a permanent-magnet generator directly connected to the main shaft and provided with overspeed trips. Two 78 in. diameter electrically operated butterfly valves furnish an emergency shut-off upstream of the turbines. Power for operating the valves is supplied by battery-operated d.c. motors. The upper portion of the draught tube is lined with a plate-steel liner. Stoplog slots are provided near the lower end for downstream closure. The draught tubes for the future units are shut off downstream by reinforced-concrete bulkheads installed in the stoplog slots. Fabrication and supervision of installation of the turbines was effected by the Dominion Engineering Co. Ltd., of Montreal, Canada.

Generators.—Two 2,750 kVA (0·9 power factor), 3 phase, 50 cycle vertical-shaft generators are directly connected to the turbines. The generators operate at 333·3 r.p.m. with a terminal voltage of 6·6 kV. Direct connected self-excited exciters operate at 250 V. The

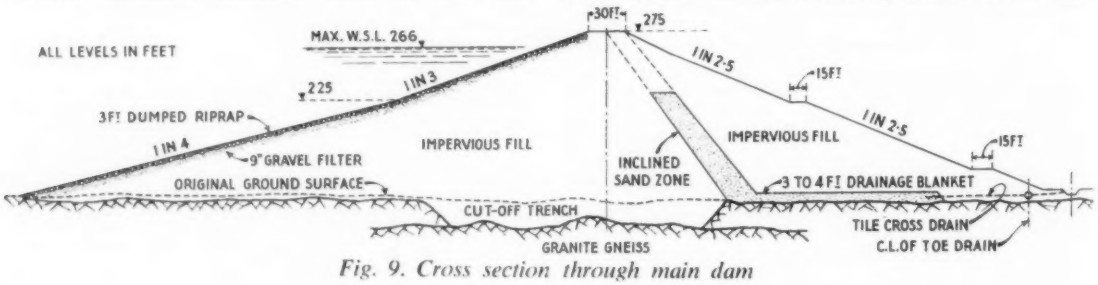


Fig. 9. Cross section through main dam

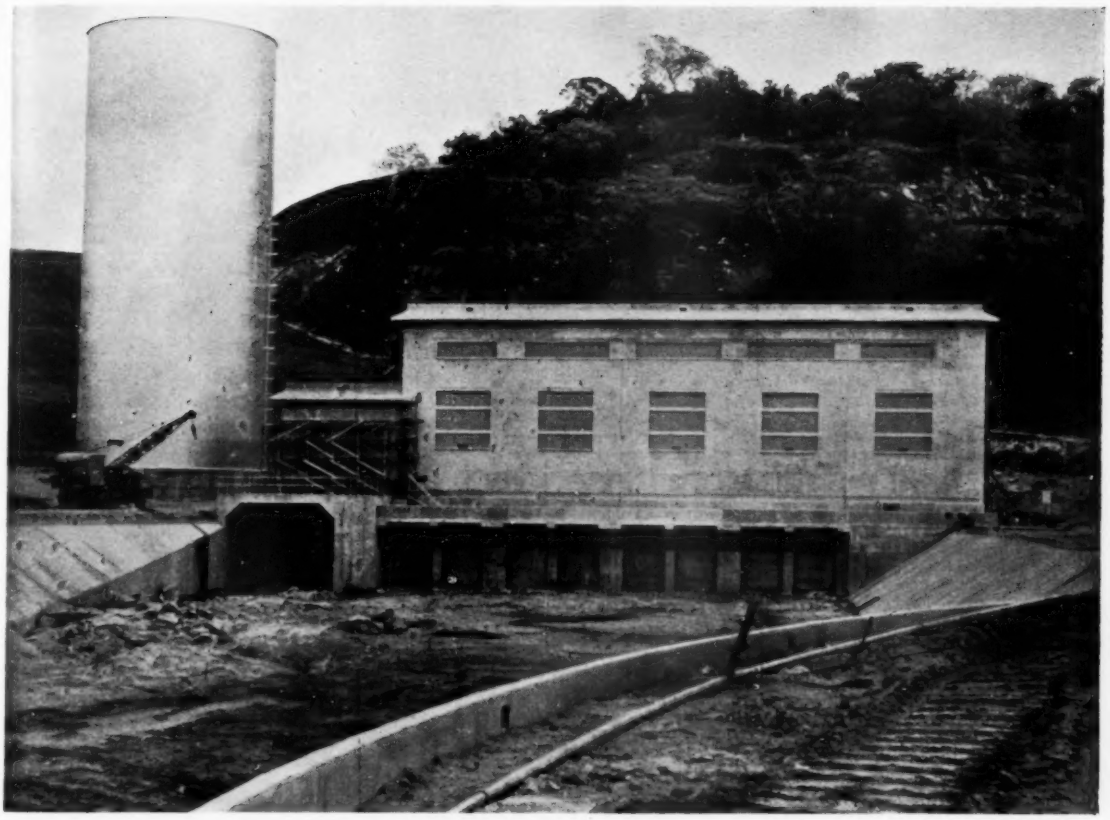
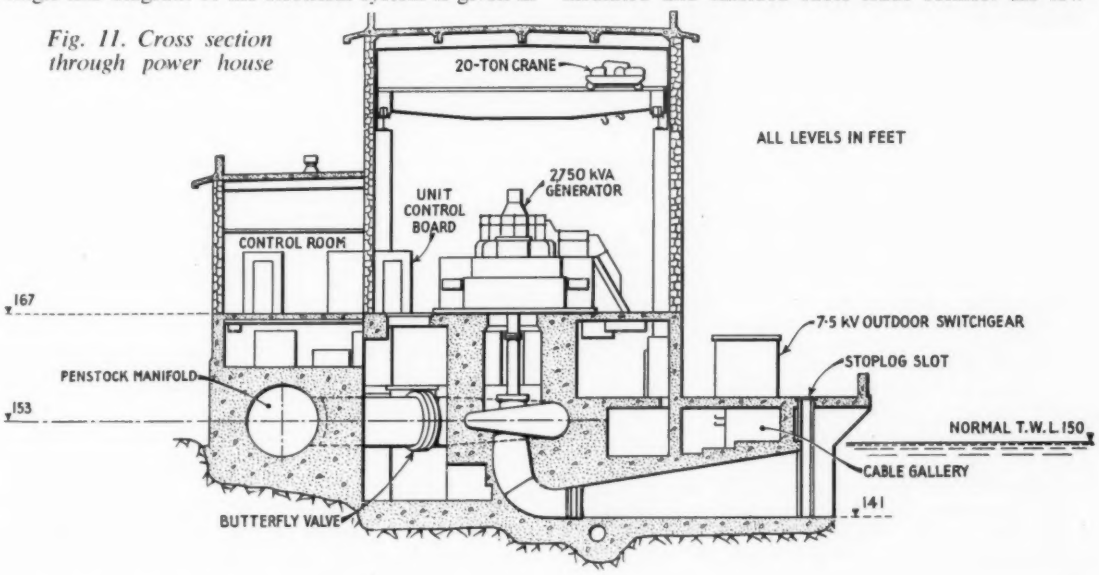


Fig. 10. Exterior of power house, surge tank on left

generators are provided with automatic CO_2 fire control equipment. Fabrication and erection of the generators was performed by International General Electric Company of Schenectady, New York.

Switchgear and Main Transformers.—A simplified single-line diagram of the electrical system is given in Fig. 4 (last month). Generator leads are connected to a common 6·6 kV bus by low-voltage switchgear located on the draught-tube deck of the power house. The switchgear, nominally rated at 7·5 kV, is of the outdoor metalclad type. Single-conductor stranded insulated and shielded cable leads connect the low-

Fig. 11. Cross section through power house



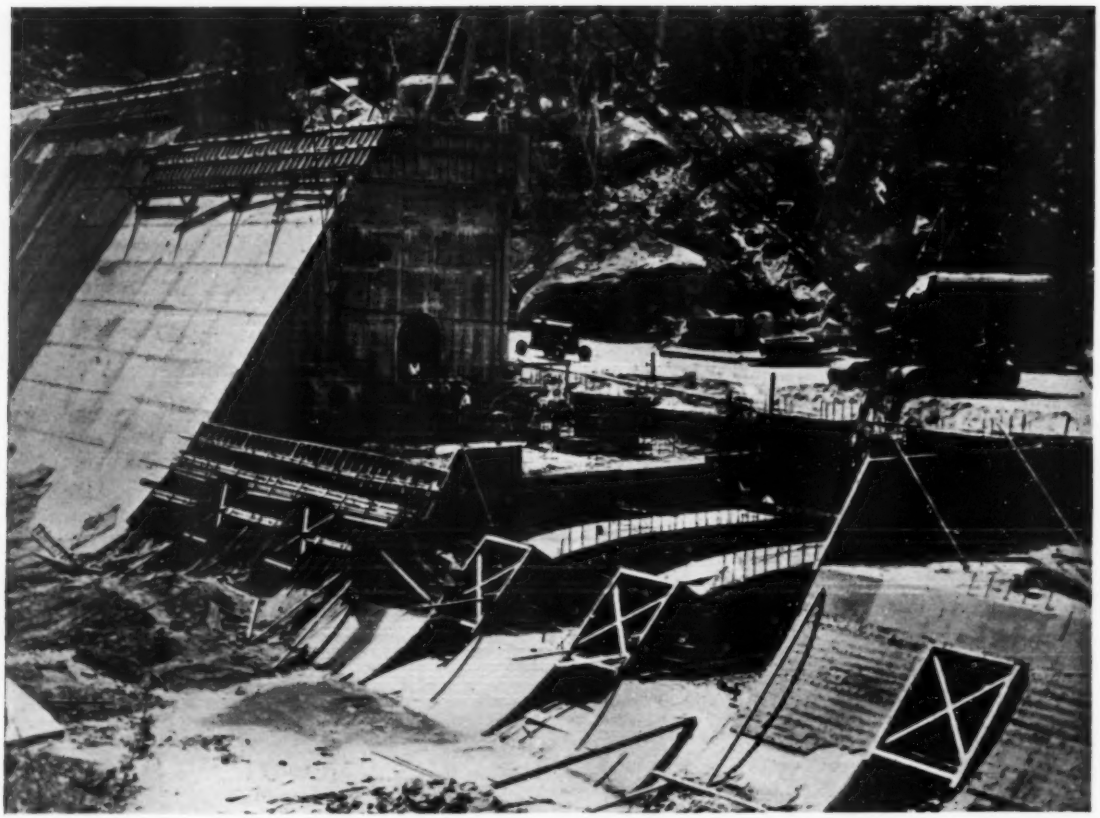


Fig. 12. Pouring concrete in spillway dam

voltage bus to the main transformer bank where generator voltage is stepped up to 66 kV. Three single-phase transformers are arranged in a delta-star bank rated at 5,000 kVA. A fourth transformer serves as a spare. The transformers, which are located in the switchyard area, are of the oil-immersed self-cooled outdoor type and are provided with single-pole lightning arrestors. They are mounted on flanged swivel-type wheels for moving the transformers on tracks to the power house for servicing. An oil circuit breaker with an interrupting capacity of 1,000,000 kVA is provided on the leads to the high-tension bus in the switchyard. Leads from the low-tension bus are carried to a 500 kVA, 11—6·6 kV transformer for power supply to the village of Inginiyagala and the spillway dam. Leads from the low-tension bus also supply station service power through two 150 kVA, 3 phase, 4-wire, 6,600 delta—415Y/240 transformers regulated by low-voltage drawout-type air-break switchgear. An 125 kVA, 3 phase, 50 cycle, 415 V petrol-engine-driven emergency generator is provided for station service. Direct current for control purposes is supplied by a 250 V alkaline (nickel-iron) battery with a dry-plate rectifier-type charger.

Duplex-type vertical control panels contain frequency standards and comparators; also recording instruments for generator temperature and output.

All equipment is protected against rapid deterioration by the high temperatures and humidity at the site and against possible attack by rodents, insects and fungi. All metal surfaces are covered with baked enamel having a fungicidal additive.

Diversion

Diversion of the Gal Oya for construction of the main dam was carried out in two stages. During the first-stage diversion, embankments were placed on both banks of the stream and the flow carried in the natural stream channel. In the channel section, the embankments were sloped somewhat steeper than 1 in 2 and the lower portions of the slopes paved with riprap. The entire spillway dam, the 3,500,000 cu. yards of fill in the main dam, the intake tower and the conduit were completed during this stage.

Second-stage diversion was commenced in April, 1951, by closure of the stream at the upstream toe of the dam with an earthfill cofferdam provided with a sheet-pile cutoff. Dry-season flow was carried in the outlet conduit. A section of conduit just upstream of the surge tank tee was not erected prior to diversion and a temporary reinforced-concrete elbow was fastened to the end of the conduit to divert the flow to the river in a temporary channel. Upon completion of the embankment, the conduit intake was closed, the diversion elbow blasted out by suitably placed dynamite charges; and the closure section of the conduit then installed.

The top of the upstream cofferdam was at elevation 174, providing a relatively low diversion capacity of about 3,200 cusecs. Rather than expend valuable

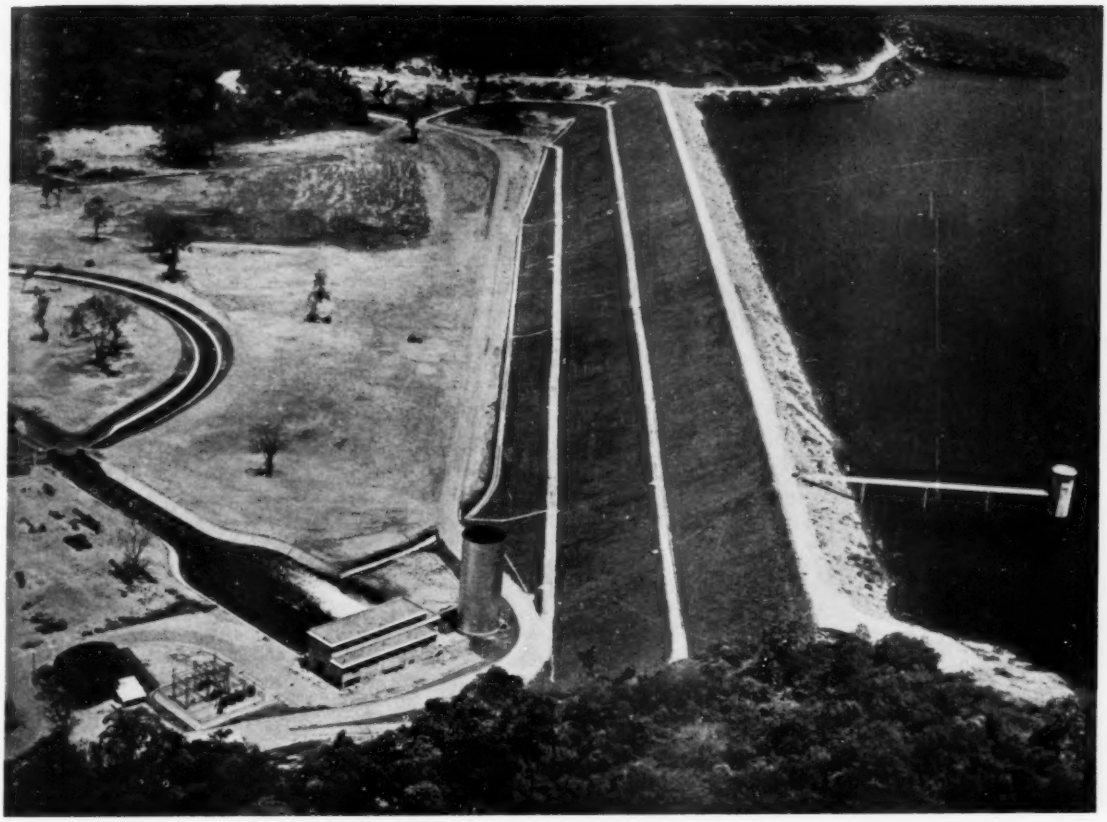


Fig. 13. Air view of Gal Oya dam showing power house in left foreground

working time in placing temporary fill, the upstream portion of the dam embankment was raised to elevation 190 as soon as possible, thus making it act as a cofferdam and thereby increasing diversion capacity to 4,500 cusecs. The embankment closure section was completed in advance of the monsoons but had this feat not been accomplished, the sluices in the spillway dam would have supplied additional capacity. A flood of 50 to 60 thousand cusecs (about 60 per cent. of the maximum flood of record) occurred during the 1949-50 north-east monsoon. No damage to the dam resulted although a substantial portion of the construction village was inundated.

Prior to placing embankment material in the closure section adjacent to existing fill, all material which had become soft was removed until well-compacted fill was exposed. Approximately 1,500,000 cu. yards of earth material were required to make the closure section of the embankment.

Irrigation Canal System

Canals were constructed on both banks of the river in order to permit irrigation of as much land as possible by a gravity flow system. Two-thirds of the irrigation supply is carried in a 50 ft. wide canal down the left bank and the remaining third in a 35 ft. wide canal down the right bank. The power-house channel leads to a trifurcation structure. Two 15 ft. by 8 ft. radial gates regulate flow to the left-bank canal, one similar gate regulates flow to the right-bank canal, and a 15 ft. by 10·75 ft. radial gate controls discharge to a wasteway to the river. The section of the canal which passes through the landscaped area at the toe of the dam is concrete lined and the remainder unlined.

The design of the canal system differs considerably from U.S. practice in that the canal sections in long reaches are of the single-bank type. At low points in the alignment, embankments or "bunds" are constructed on the river side of the canal only. The water is thus allowed to spread on the land side forming intermediate tanks at these locations, some with a considerable capacity.

The design and construction of the canal system was undertaken initially by the Department of Irrigation with its own personnel and equipment. After the Irrigation Department had completed one mile of the left-bank canal, an agreement was completed with Morrison-Knudsen International Company Inc., to construct the trifurcation structure and complete the first 7 miles of the left-bank canal. The designs of the Irrigation Department were used generally, the Engineering Department of Morrison-Knudsen International furnishing designs for several control structures. Late in 1951 a second supplemental agreement was signed under which Morrison-Knudsen International continued the left-bank canal to Mile 13 and began construction of the right-bank canal. Designs for the canal section, alignment and grades were furnished by the Irrigation Department and for

the control structures by the Engineering Department of the contractors.

Contractor's Plant and Equipment

A well-equipped construction plant was established in the vicinity of the left abutment of the main dam. Facilities constructed included machine and electrical shops, garages, warehouses, a sawmill and a carpenter's shop. Power for the construction plant and the village was supplied by two diesel-driven 400 V, 3 phase, 50 cycle a.c. generators with an overall rated capacity of 938 kVA.

An electrically operated crushing and screening plant was erected for the production of concrete aggregate for the job. Material for the crusher was obtained from a quarry site upstream of the spillway dam. Crusher sand was blended with river sand to produce fine aggregate. An electrically operated batching and mixing plant produced the concrete, which was hauled to the forms on trucks and placed by cranes in 1 and 2 cu. yard buckets (Fig. 12). Cement was procured primarily from Sweden and Belgium.

All equipment used on the project was turned over to the Irrigation Department by the contractor in working order following the completion of the job. The construction power plant was transported to the town of Ampari, 12 miles downstream and installed permanently there.

Overall cost of the Gal Oya dams and power plant was 10,261,000 U.S. dollars. A view of the completed main dam and power plant is shown in Fig. 13.

Construction Camp and Personnel

Carefully selected American personnel were employed in Ceylon to supervise the various construction, engineering, shop and equipment maintenance operations for the contractor. A maximum of about 3,680 and an average of about 2,000 Ceylonese were employed by the contractor on the job. They served both as skilled and unskilled labourers and in the engineering and administrative offices. Men with no previous experience were trained quickly to become competent operators of tractors, shovels and trucks.

The construction village of Inginiyagala will serve permanently as the operator's village. The water supply is treated by a pressure-type filter and a chlorinator which were installed as permanent features of the project. A sewerage system was also provided in the village. Hospitalisation and medical care were supplied for all personnel at the site.

The Irrigation Department maintained administrative and engineering offices and laboratories for inspection purposes. The Director of Irrigation was responsible for engineering and supervision of construction for the Ceylonese Government. During the course of the job, S. G. Taylor, W. A. Guthrie and W. T. I. Alagaratnam successively held the office of the Director of Irrigation. M. C. Abraham and H. O. T. Scharenquivel held the post of Resident Engineer on the job for the Irrigation Department. D. W. R. Kahawita was responsible for approval of all designs. Jahangir Singh was the engineer in charge of canals and J. Canagarathnam soils engineer.

The Gal Oya Development Board, which will operate the project, was initially under the direction of James Huxham, Chairman. He was succeeded by K. Kanagasundrum.

Design and construction were under the general supervision of C. P. Dunn, Vice-President and General Manager of Morrison-Knudsen International Company and President of International Engineering Company. E. F. Koerner is Manager of Construction Operations and E. N. Benson, Business Manager for Morrison-Knudsen International Company. H. B. Olson was Project Superintendent for Morrison-Knudsen International Company. G. J. Gavin and E. M. Bowles were Project Engineers and N. G. Adams Electrical Engineer on the job. D. J. Bleifuss was Chief Engineer and B. M. Johnson Chief Designing Engineer for International Engineering Company.

St. Anthony Falls Laboratory

Circular No. 3 issued by St. Anthony Falls Hydraulic Laboratory, a department of the University of Minnesota, gives a current list of publications and motion pictures which have been prepared in connection with the work carried out in the laboratory. The publications comprise bulletins, circulars, technical papers and project reports, the last-named not being available for purchase. The films, some 26 in all, have been prepared primarily for use by the laboratory staff, but they can be hired out to responsible engineers and educational authorities. They deal with such subjects as hydraulic model studies, flow diversion by guide vanes, fabrication techniques for hydraulic models and so on. The circular is available on application to The Director, St. Anthony Falls Hydraulic Laboratory, Hennepin Island, Minneapolis 14, Minnesota, U.S.A.

"Batcherplants." Catalogue No. 105 produced by Blaw Knox Limited refers to the complete range of central concrete-mixing plants, batching plants, bulk cement plants and material-handling equipment manufactured by this firm. The illustrations consist of both photographic reproductions and dimensioned drawings and the descriptive matter is technical and detailed. Colour has been liberally used, and the colour photograph of the "Batcherplant" supplied for the construction of the 922 ft. Grande Dixence dam, Switzerland, makes one of the most striking covers we have ever seen on a catalogue of this kind.

Ransomes and Rapier Limited have issued a special edition, in Arabic, of their illustrated folder "What We Make" for distribution by their agents, Iraq Mercantile Limited, at the Baghdad Trade Fair. Other publications are concerned with Rapier mobile cranes, shop truck cranes, excavators of various kinds, and water control gates.

British Insulated Callender's (Submarine Cables) Limited. A firm under this title with an authorised capital of £250,000, has been formed by British Insulated Callender's Cables Ltd. and W. T. Glover & Co. Ltd. to specialise in the design and manufacture of submarine power cables. The Registered Office of the Company is Norfolk House, Norfolk Street, London, W.C.2., and the Works are at Trafford Park, Manchester. During most of 1955 the Company will be occupied with the manufacture of approximately 77 miles of 138 kV 0.35 sq. in. gas-filled submarine power cable for the British Columbia Electric Co. Ltd. of Canada to the order received by one of the parent companies.

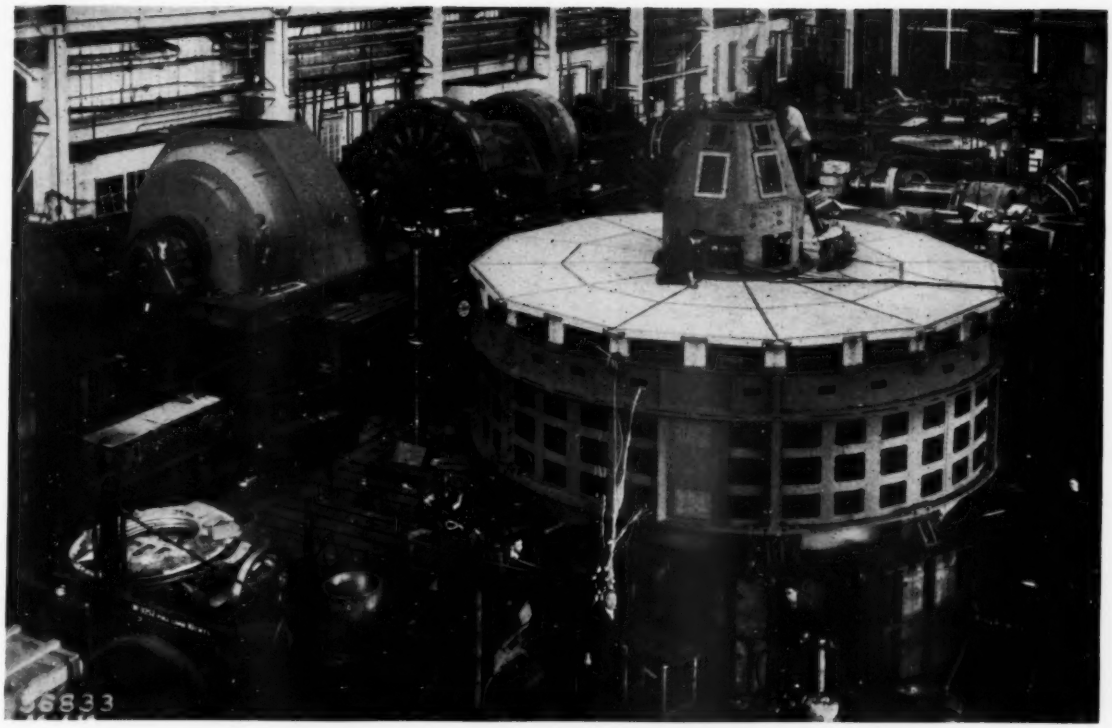


Fig. 1. The 40 MW vertical alternator for Roxburgh and the 30 MW horizontal alternator for Finlarig on test in the B.T.H. heavy-plant factory

Large Waterwheel Alternators on Test

DURING a recent visit to the Rugby works of the British Thomson-Houston Co. Ltd. we had the opportunity of seeing two large waterwheel alternators on test, one being a 40 MW vertical machine for Roxburgh, New Zealand, and the other a 30 MW horizontal machine for the North of Scotland Hydro-Electric Board's station at Finlarig. The machines are seen on test in Fig. 1.

This event was of interest for two reasons: In the first place it is becoming more usual to avoid the complete erection of such large machines in the shops, and secondly, the occasion afforded a demonstration of heavy-plant test facilities that the Company have installed recently and which may well be unique.

A brief account of the Roxburgh scheme was given in our June 1953 issue. This scheme will harness the waters of the Clutha in the southern island, the largest river in New Zealand, and will have an ultimate capacity of 320 MW in eight sets, four of which are on order. The station will be situated at the foot of a mass concrete gravity dam located at the downstream end of a deep gorge, creating a head of 148 ft. at a point where the natural flow of the Clutha is 18,000 cusecs.

The turbines, which will be of the Francis type, are being manufactured by the Dominion Engineering Company, Montreal. It has been specified by the customer that the alignment of turbine and alternator shafts should be checked before delivery to site, and the turbine manufacturers are delivering each turbine shaft as completed to the B.T.H. works, where it is bolted to its corresponding generator shaft and the assembly mounted in a centrelathe for checking the alignment.

The alternator we saw on test is the second of the four machines on order; the first machine has left the factory and many of the parts, including the stator sections, have been cocooned to prevent deterioration during transit and while awaiting erection.

Each alternator is rated at 44,444 kVA, 11 kV, three phase, 50 cycles, 136 r.p.m., and is 29 ft. in overall diameter, 27 ft. 6 in. high, and weighs 350 tons. The stator is divided into six sections and is of fabricated construction. The rotor is of the laminated-rim type common to low-speed machines. On the shaft are two forged flanges to which are bolted heavy steel discs, and between these discs are bolted eleven radial arms, slotted at their outer ends, forming a spider. Around this spider the laminated rim is built up from segments punched in $\frac{1}{4}$ in. plate and held together by close-fitting bolts, the complete rim being held to the spider by taper keys. The pole pieces consist of laminations held between forged endpieces and are provided with damper windings.

The thrust bearing is carried on a fabricated bottom bracket immediately below the rotor, and is designed to carry a load of 375 tons including the hydraulic thrust. It is of the Michell pivoted-pad type and is submerged in oil which is pump-circulated to an external cooler. A Michell-type guide bearing is incorporated with the thrust assembly, and owing to the length of the rotor (65 in. over the poles) an upper guide bearing is also provided. Main and pilot exciters and a permanent-magnet pendulum generator are coupled to the shaft above the upper guide bearing.

Pneumatically-operated brakes mounted on the arms of the bottom bracket engage a ring of polished steel segments on the lower face of the rotor; these brakes can also be supplied with high-pressure oil to act as jacks for thrust-bearing inspection.

Finlarig station, at the western end of Loch Tay, will form one of a group of five stations constituting the North of Scotland Hydro-Electric Board's Lawers scheme. It will draw its water from Lochan na Lairige, lying at 1,620 ft., which will be raised 90 ft. by a dam 1,250 ft. long and 130 ft. high and will receive the flow of a number of mountain streams on Ben Lawers by a system of aqueducts. A tunnel about 2 miles long has been driven to a surge chamber and valve house from which the station will be fed by penstock.

The turbo-alternator will be the largest horizontal hydro set yet installed in Great Britain, and it will operate on the highest head—1,348 ft. gross—used so far on any of the Board's projects. The turbine is being built in Scotland to the design of Boving & Co. Ltd., and will be of the twin overhung-runner Pelton type, with two jets per runner. Each runner will weigh about 5 tons, and will consist of a forged-steel disc to which are bolted 18 buckets made of cast stainless steel.

The set runs at 375 r.p.m. and is designed for a runaway speed of 705 r.p.m., the alternator rating being 35,294 kVA, 11 kV, three phase, 50 cycles, 0·85 power factor.

To comply with transport limitations the stator is split along the horizontal centreline. The winding is of the double-layer Roebel bar type, and the fully wound stator weighs 58 tons.

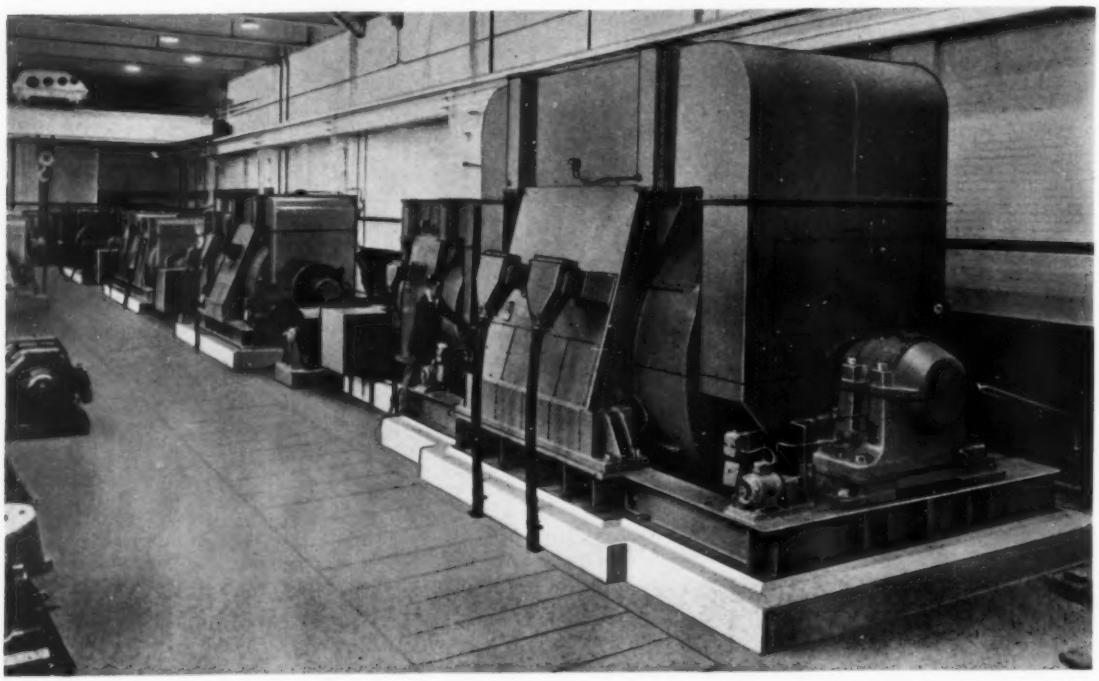


Fig. 2. Test machine room, with a 20,000 kVA motor-alternator set in foreground

The rotor comprises a shaft, nearly 30 ft. long, on which are shrunk and keyed a series of steel plates, 7 in. thick, to form the rotor body, flats and dovetail slots being machined on the body after assembly to carry the poles, of which there are 16. The complete rotor weighs 127 tons, and as this is too heavy to be transported to site, all the poles and four of the plates will have to be removed to bring the weight down to a permissible 77 tons.

The alternator bearings are of the Michell type and are fed with oil from an external circuit.

To reduce the overall length of the set, and thus to save power-house space, the main exciter is located between the stator and the main bearing at the end opposite to the sliprings, the pilot exciter and pendulum generator being flexibly coupled to one Pelton runner. By this means about 4 ft. has been saved on the length of the set.

These two machines were being subjected to a comprehensive series of tests, including running "back-to-back," and this leads us to a description of the equipment installed for testing heavy plant. The main problems in designing test generating plant are those of providing sufficient capacity to test heavy equipment and of affording the requisite diversity of

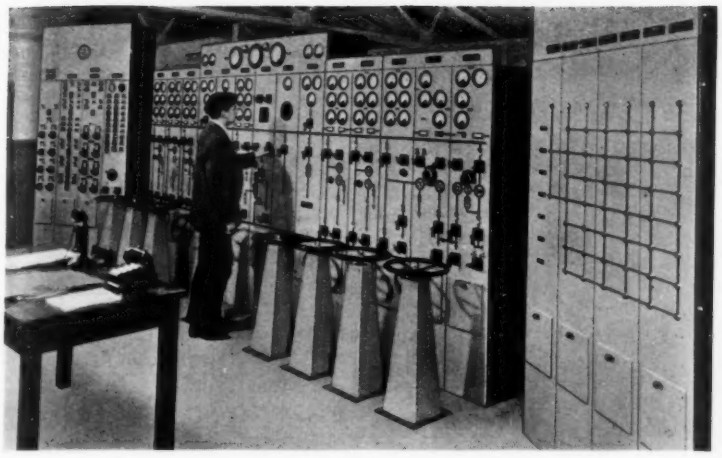


Fig. 3. Test-plant control room

supply to test all kinds of a.c. and d.c. rotating and static plant. It was therefore decided to install a central test generating plant (Fig. 2) of substantial capacity, both a.c. and d.c., with provision for extension and with facilities for making the output available at various places in factories other than the new Heavy Plant Factory, where the test plant is located.

The two main d.c. generators are each rated at 700 V 2,400 A; they both run at 1,500 r.p.m. and are driven by 2,000 kW a.c. synchronous motors. Their output, and that of a number of smaller auxiliary sets, is used chiefly for testing large d.c. motors and alternators driven from test-plant motors in the Heavy Plant Factory. It is also used, however, for supplying the driving motor of the new Overspeed Test to be described later. The two generators can be used singly, in series, or in parallel.

The a.c. generating plant had to meet the somewhat conflicting requirements of simultaneous availability in diverse places and of occasional large demands in any one spot. It was therefore subdivided. Alternators of 20, 5 and 1 MVA were first installed, each driven by a synchronous motor; a further 5 MVA alternator is being installed and provision has been made for one of 10 MVA. All the alternators generate at 12 kV and have similar characteristics, so that while they are normally used independently, they can, when occasion demands, be used in parallel. Using the motor of one of the d.c. generators as a synchronous condenser has already enabled an output of 28,000 kVA to be produced for testing the first 120 MVA, 275/132 kV transformers for the B.E.A.

This varied output is made available at five points in the Heavy Plant Factory—in the Generator Factory, in the Turbine Factory, and in the Motor-Compressor Test House, which is a third of a mile away. At each location there is full control of alternator voltage, switching and protection: or if the two d.c. generators are used as a Ward-Leonard system, of frequency. Interlocking for safety and fault protection has been provided on an extensive scale. The selection of any one, or several, alternator outputs for any test station is accomplished by a simple switching operation. A central control room (Fig. 3) provides the test staff with a complete picture and overriding control of the output of the plant, the condition of which is shown on a miniature control board.

Starting the alternator sets is something of a problem, and this has been overcome by providing one a.c. and one d.c. set only with pony-motor starting. All other sets are started on variable voltage, usually from the a.c. set, before being synchronised on to the main incoming 12 kV line. The synchronous motors are considerably smaller than the alternators, since the amount of power is much less than the kVA.

For testing transformers, provision has to be made for certain requirements which do not exist in machine testing. These are mostly concerned with high voltages. Every transformer has to be subjected to an over-voltage test, at a frequency which will prevent saturation of its core. The supply for this, channelled through the system already described, is obtained from a special 250 cycle alternator rated at 4,000 kVA for short periods.

The new rotor-balancing and overspeed test house has been designed not only to test the largest steam turbo-alternator rotors envisaged but also to accommodate waterwheel alternators up to 14 ft. in diameter. It forms a separate building, the overspeed tunnel itself being 18 ft. in diameter and 48 ft. long and is of reinforced concrete with a thick lining of timber and sand. At one end of the tunnel is a loading bay in which a 120 ton crane places the rotor on bearings on self-propelled carriages, which move into the tunnel under their own power and are then bolted down. Motor-driven bulkhead doors then close the entry. At the opposite end the drive shaft is taken through a bulkhead to a 3,000 h.p. (peak) d.c. motor. This motor is supplied from the central test plant already described, and is Ward-Leonard controlled, giving smooth acceleration, precise speed control, and

Fig. 4. Overspeed-test control desk

regenerative braking. A range of interchangeable step-up gears enables the appropriate speed range to be selected for the rotor under test, and a rotatable lining-up disc surrounding the drive-shaft flange greatly simplifies the work of lining up the rotor.

All control is centred on a control board in a separate room. Instruments on this board show vibration amplitudes down to 0·0001 in. and also show the angular position of out-of-balance forces at each end of the rotor.

While a rotor is in the test house for balancing and overspeeding, certain other processes and tests can be applied. A heavy-current d.c. generator is installed for heating and drying out rotor windings. A high-voltage transformer and regulator provide for high-potential tests on rotor windings, and insulation resistance to earth and winding resistance can be measured while the rotor is still inside the overspeed tunnel.

A view of a 36,000 kVA waterwheel-alternator rotor for the Artias station, Spain, about to enter the overspeed tunnel was given on page 199 of our May 1954 issue, and the overspeed-test control board is depicted in Fig. 4.

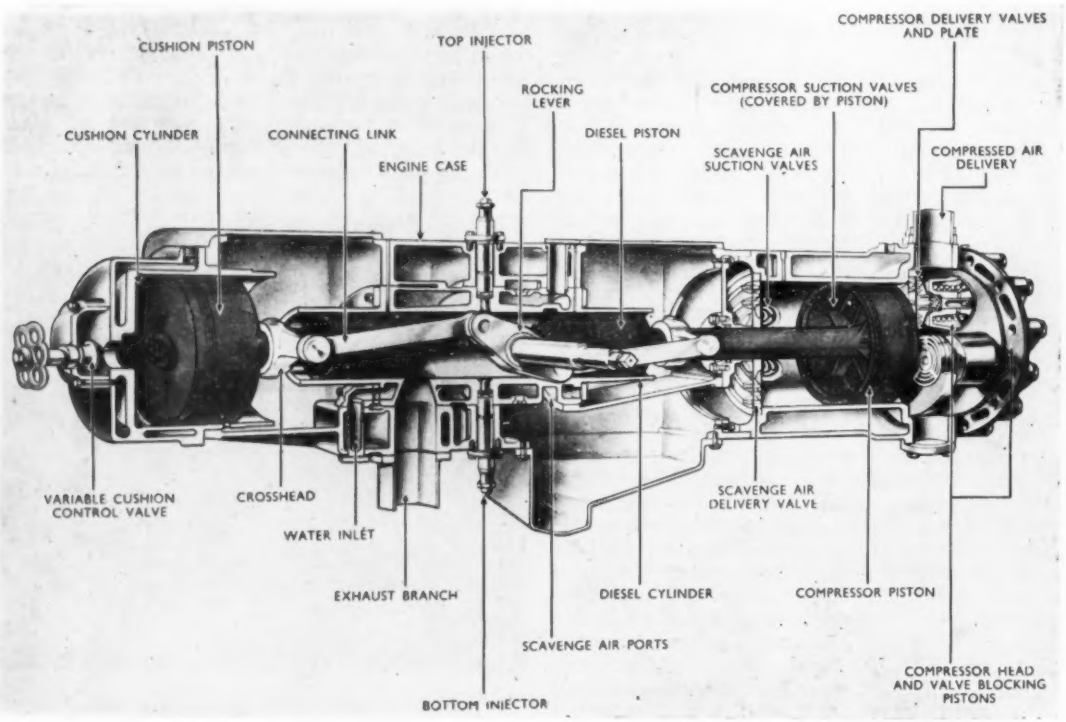
The capital expenditure incurred by the British Thomson-Houston Co. Ltd. in providing these lavish test facilities must have been very considerable, but the Company feels the expenditure to be justified because the equipment is used not only to check performance guarantees but also to provide fundamental test data on which the future design of heavy plant can be based. The value of obtaining practical design data in this way cannot be overstressed.

Free Piston Compressor

Mackay Industrial Equipment Limited have been appointed sole distributors in the British Isles (including Eire) of the Pescara-Muntz free-piston portable air compressor. This machine is manufactured by Alan Muntz & Co. Ltd., who hold the licence in the British Commonwealth for Pescara patents.

As the accompanying diagram shows, the power unit consists of a single diesel-engine cylinder in which two opposed pistons operate on a two-stroke cycle, one piston being connected in tandem with an air-compressor piston while the other is similarly connected to a cushion piston to store up energy for the return stroke and so maintain the firing cycle. No flywheel is thus necessary. These two groups of moving parts are kept in phase by a lightly-loaded link gear connected at the outboard ends to crossheads on the piston rods, and at the inboard ends to rocking levers carried on rocking shafts. By this arrangement the normal necessity to have two crankshafts, with their incidental connecting rods, bearings, and clutch or coupling, is eliminated, and as both groups of moving parts are balanced and opposed, there is a total absence of vibration. Starting-up is effected by giving 28 easy turns to a handle, this operation compressing a powerful spring which, when automatically released, causes the diesel pistons to approach at exactly the same speed as the normal working stroke. Immediate starting is thus assured in all temperature conditions down to minus 18°C.

The cylinder bore is 4·25 in. and regulation of the compressed-air output is effected by varying the stroke —this variation ranging from 5·25 in. at no load to



5·98 in. at full load. This variation is controlled automatically by a sensitive regulator which operates from the air-receiver pressure, and which also controls the supply of fuel injected into the diesel cylinder.

The rated output of the P.42 type compressor is 105 cu. ft. per min. at a maximum operating pressure of 100 lb. per sq. in. Under normal working conditions the fuel consumption amounts to about 7 pints per hour, but if the idling time is high the consumption is claimed to be extremely low as the equipment is very economical on partial loads. The weight of the complete unit, when mounted on a two-wheeled chassis fitted with pneumatic tyres, over-run brakes and incorporating two tubular air receivers, is 3,400 lb. A complete outfit of pneumatic tools and two hose reels can be carried under the canopy.

Lighting at Owen Falls

The accompanying illustrations show part of a special lighting scheme which was prepared by The General Electric Co. Ltd., in conjunction with the consulting engineers, Sir Alexander Gibb and Partners, for the new Owen Falls hydro-electric station of the Uganda Electricity Board. The G.E.C. switchboard in the control room (Fig. 1) is for remote supervisory operation of the outdoor substation, for which twelve 33kV oil circuit breakers and 45 rotary isolators (43 for 33kV and two for 66kV) were supplied by this company. Here a continuous rectangular fitting, supporting a metal louvre, and with reeded glass sides is partly recessed into the ceiling, the 24 Osram 5 ft. 80 W Warm-White hot-cathode tubes providing an average service illumination of 15 lumens per sq. ft. To light the walkway behind the control boards four 100W recessed tungsten units are mounted one in each corner of the room; and to provide additional lighting for the vertical surfaces of the panels two Osram 150W spotlight reflector lamps, with internally silvered bulbs in spun aluminium housings, are situated above the controller's desk.

In the entrance hall (Fig. 2) four cornice features in white stove enamelled sheet steel contain a single line of Osram-Warm-White cold-cathode tubing.

In the conference room (not illustrated) a specially designed suspended fitting accommodates 68 ft. of Osram Warm-White cold-cathode tubing operated at 120mA to provide the main illumination. Four 100W louvred tungsten fittings recessed in the false ceiling provide additional illumination. The electrical contractor for this lighting scheme was Electrical Installations Limited of Vincent Square, Westminster, S.W.1.

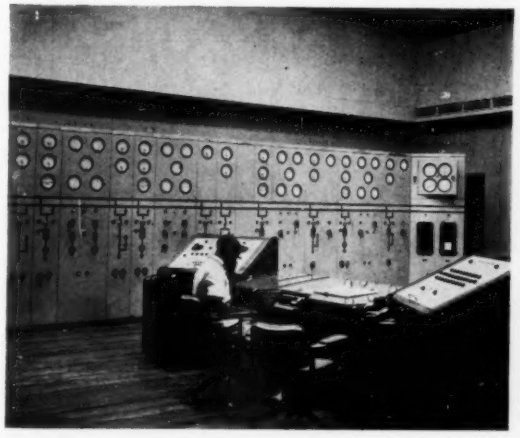


Fig. 1. Owen Falls control room

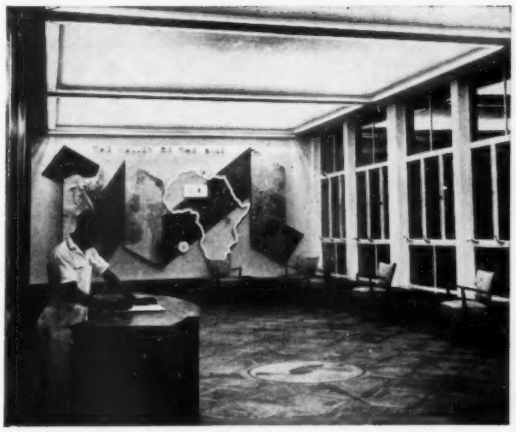
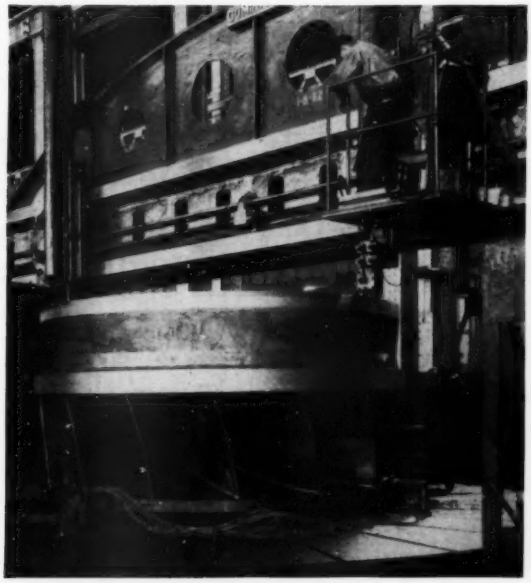


Fig. 2. Owen Falls entrance hall

Large Turbine Runner

The accompanying illustration shows one of the most powerful Francis turbines to be put into operation in Canada. It was designed and built by Dominion Engineering Works Ltd. and will develop 120,000 h.p. under a net head of 200 ft. at a speed of 120 revs. per min. Two of these turbines have just been put in operation at the Waneta B.C. Power Plant of the Consolidated Mining and Smelting Company Ltd., and our photograph shows one of the units being machined on a 42/52 ft. vertical boring mill at the Dominion works.



Dominion 120,000 h.p. runner for Waneta

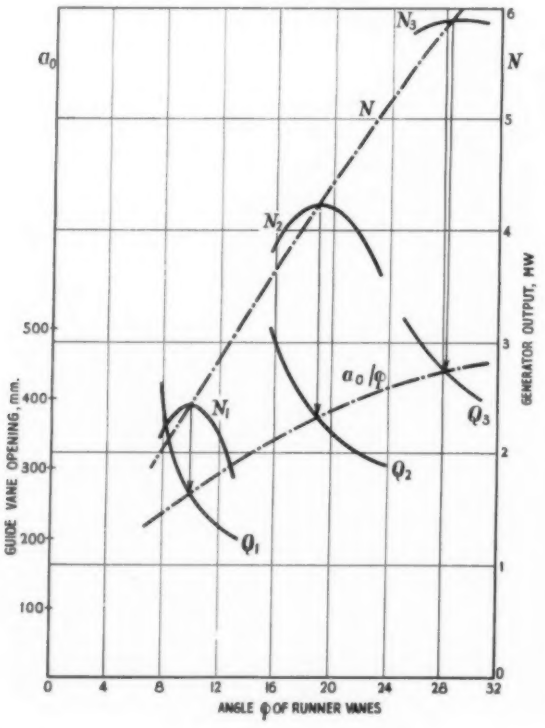
Abstracts from the World Technical Press

Tuning-in Kaplan Turbines

Experience has shown that the opening times a_o/γ determined by turbine manufacturers either theoretically or with the help of model tests are, as a rule, approximately correct but may be improved in actual practice. A method is advocated which not only simplifies the measuring process but also shows the results while tests are still in progress. Even if this method does not enable absolute efficiency to be computed, it gives a fair guarantee that Kaplan turbines can be tuned-in in practice to the highest possible degree of efficiency. It fundamentally consists in passing one and the same discharge through the turbine at various openings, and in measuring the resulting output of the generator; this implies, hydraulically speaking, that there is an optimum opening which brings about the highest output and also the maximum degree of efficiency. The absolute discharge can be disregarded when applying this method.

The tests should be carried out in five different ranges and, if possible, at a constant operating head, though the repercussion of head variations on the a_o/γ ratio is hardly noticeable; the more tests there are in each range, the greater will be the accuracy of the plotted curve. In each test, the runner vanes are set at any angle, and the guide-vane opening is widened or narrowed until the discharge selected for each range of tests is reached, and settled conditions achieved. The generator is then set at cos $\gamma = 1{\cdot}0$, and its output read; at no further than the second test, the increasing or decreasing output enables it to be ascertained whether the turbine is moving towards its optimum setting or away from it.

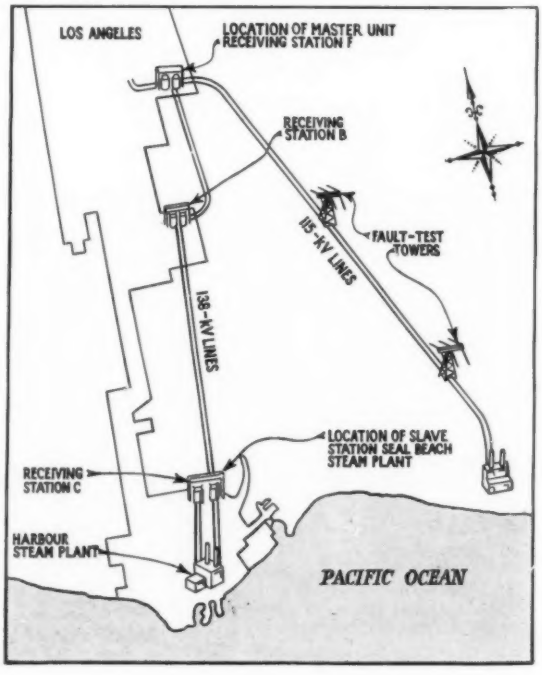
This simplified method was applied at the Altheim plant of the Bayernwerk A.G. to a turbine discharging 90 cu. m. per second at a head of 8·3 metres, 35 tests being made in five ranges within four hours. For the sake of clarity, the number of ranges has been restricted to three in the appended diagram. The resulting curve proved identical with the curve obtained with the help of an accurate propeller meter and, by means of the new a_o/γ curve, it was found possible to improve the efficiency of the turbine by about 1 per cent. (Anton List, Bayernwerk A.G., Munich, *Die Wasserwirtschaft*, Vol. 44, No. 4, Jan. 1954, p. 104, 2 pp., 1 f.)



Locating Faults on Live Transmission Lines

A new all-electronic fault-locating system is described. The system, continuously monitoring an energised transmission line, has located faults accurately in recent field tests on the network of Los Angeles Department of Water and Power. Simulated faults were localised to the exact tower on a 23-mile stretch of 115 kV line, although the designed accuracy calls only for location within about $\pm$1,000 ft. On the test line between Seal Beach Steam Plant and Receiving Station *F* several faults were applied to two towers, each about one-third of the distance from the opposite ends of the line.

The electronic system has a master station at one end of the line and a slave station at the other end; the master station includes a 100-kc transmitter, a micro-second counter, a 1-mc temperature-controlled crystal oscillator, and a fault receiver. The slave station equipment is almost identical, a 100-kc synchronising unit being substituted for the transmitter; both stations connect to the transmission circuits through standard high-voltage coupling capacitors.



The fault tests were very simple: four 20 ft. lengths of No. 24 iron wire, each with a 2 lb. weight, were attached over the armour rod on the lowest phase conductor while the line was de-energised. The wires, spaced about 3 ft. apart and away from the insulator string, were pulled away from the tower by lengths of string to an angle of about 30 deg. Once the line was re-energised, mobile radio co-ordinated the release of the wires one at a time with operations at both ends of the line. The wires fell against and shorted to a horizontal grounding bar attached to the tower to prevent damage. Criterion for successful operation of the electronic fault locator was its ability to measure accurately the time in micro-seconds taken by the travelling fault to reach the line's end. By referring the time to a specially calibrated chart, the point of fault can be located within ± 984 ft., the approximate distance an electric wave travels in one micro-second. A one-micro-second error is tolerable. (*Electrical World*, Vol. 141, No. 13, March 29, pp. 30/31, 4 ff.)

Yukon and British Columbia

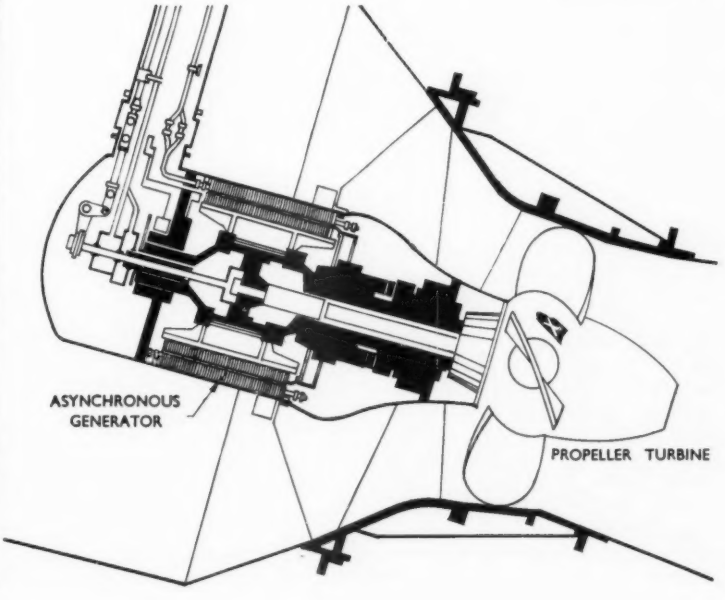
An account is given of the negotiations and investigations connected with development programmes in British Columbia and the Yukon Territory which would lead to some 11 million kW of capacity at a roughly estimated cost of $2·2 billion. The principal rivers involved are the Yukon, Columbia and Fraser. Frobisher Limited, of Toronto, have plans to develop the Yukon River Basin for the ultimate installation of 3·4 million kW at a cost of about $700 million, while the Aluminium Company of America would harness the Yukon in Canadian territory east of the Alaska border, and divert water to U.S. territory for use in a smelter at Skagway, Alaska. Canadian and U.S. interests are thus clashing, an important Canadian objection to the Alcoa scheme being that its Skagway smelter would be able to ship aluminium to U.S. without tariff and so undercut Canadian aluminium in the U.S. market. There are, however, indications that the discussions held a short time ago between the two companies and with Premier Bennett, of British Columbia, may lead to a joint undertaking to develop the hydro resources of the Skagway hinterlands.

The main feature of the plans for the development of the Canadian stretch of the Columbia River is a 600 ft. high dam at Mica Creek which would impound 15 million acre ft. of water and develop 750,000 kW from a head of 1,100 ft. Nearly $3 million has been spent in the surveys, and it is announced that work on the structure, whose completion would require some years, would probably begin in the latter part of 1955. Both the Canadian and U.S. sections of the International Joint Commission are expected to give their final approval to the Mica Creek project. The cost of the dam is assessed at $400 million.

The Fraser River Development is a purely Canadian venture; investigations, started in 1949 on this river and its tributaries, Thompson and Clearwater, have resulted in a programme calling for five dams to be built above Lytton. The programme involves some 3·2 million kW capacity and would cut flood dangers, the cost being $800 million. (*Engineering News-Record*, Vol. 152, No. 17, April 29, 1954, p. 23/24, 1 f.)

Castet Power Units

The outstanding characteristic of these submerged monoblock units is their uncommon compactness: they are mounted in the dam body itself at the entrance of a tapering tube which acts as a diffuser to the turbine. The runner, which develops 1,100 h.p. under a head of 7·5 m. and runs at 254 r.p.m., is of the axial-flow, adjustable-blade propeller type, and has fixed guide-vanes. The asynchronous, squirrel-cage alternator, fitted in a bulb-shaped casing up-



stream of the turbine runner between the guide-vanes, has an output of 810 kW at 500 V, with a power factor of 0·7; its overload capacity is high, and it reaches its maximum efficiency at about 75 per cent. load. The cooling oil is kept in circulation, around the moving parts and along the cap of the casing, by means of a centrifugal pump fitted on to the shaft of the rotor. The servo-mechanism controlling the adjustment of the blades is fitted inside the rotor. The thrust-bearing is inserted between the alternator and the runner in the conical section which connects them together.

The unusual pattern of these power units was selected because of the striking economies it permits in the civil-engineering works of the plant. For example, the diameter of the alternator is less than half that of the conventional type. The most conspicuous difference, however, lies in the output—1,100 h.p.—as units of conventional design, reduced to the size of the Castet sets and running at the same speed, would develop no more than 100 h.p. and 150 h.p. in enclosed and open machines respectively. The difference in weight between the two alternators is just as striking; considering the shaft, casing and bearings as parts of the turbine, the weight of a new-type unit is between a fifth or a sixth of that of normal designs. The latter scores, however, fairly heavily in the matter of expenditure, as the new type involves the use of an uncommonly large proportion of high-class material in the slots of the armature, insulation, and copper components; the manufacturing costs are also considerably higher.

Considered as a whole, however, and in spite of the fact that the structure of the powerhouse is reduced to its simplest expression, it is not established that the Castet plant costs considerably less than the usual type of low-head hydro-electric plant; we have here to deal with a prototype and, as in every prototype, economy was not the main aim its designers had in view. The alternators, taken alone, do not constitute an attempt to revolutionise electrical engineering but are simply the results of developments governed by new requirements. It is the whole power unit itself which marks a new stage in the progress of electrical and mechanical engineering, the final goal being a pattern of low-head plant which, combining optimum cost and a high mechanical efficiency, could be applied with equal success to tidal developments and run-of-river plants. (J. Guimbal, *La Houille Blanche*, Vol. 9, No. 2, p. 129, 5 pp., 8 ff.)

The Castet Dam

This is the first part of an article which deals in detail with the Castet power station. The upper Gave d'Ossau development in the Pyrénées comprises a sequence of plants regulated upstream by the seasonal reservoirs of Artouste, Fabrèges and of the Bious; the total head equipped is about 1,600 m. Downstream, scattered along the Gave, there is a chain of small run-of-river plants utilising widely differing discharges. This state of things obliged the Hourat plant, and, to a certain extent, the Miégebat plant, to maintain output at off-peak periods in order to satisfy the requirements of downstream power consumers. The French Railways, which control this development, thus decided to build a dam at Castet, downstream of Hourat and upstream of the small consumption centres, so as to provide the latter not only with an energy supply evenly spread over 24 hours while, to also to afford themselves full freedom of operation to the plants supplying their railways. The compensation reservoir created by the dam has a useful capacity of 350,000 cu. m., and extends to a length of 1,200 m.; its maximum level ensures a head of 7·8 m. above the downstream low-water level and it was subsequently found expedient to utilise this head by means of a small power station.

The dam consists of four sections: (1) a ferro-concrete screen about 50 m. in length, reinforced by uniformly spaced buttresses; (2) the sluiceway section, consisting of three piers in which the control gear is housed, and two flood passes equipped each with a roller gate; (3) the powerhouse block; (4) a dam section extending from the powerhouse to the rock head of the left bank. In the reservoir itself, a wall, acting as a gravel trap, protects the turbine intakes, and diverts non-suspended solid matter to the flood gates; this wall is normally submerged, its crest being 3 m. below the maximum reservoir level. In addition, gravel entering the enclosure formed by the wall is stopped by hoppers fitted in front of the intake screens, and from which it can be expelled into the tail water by means of a flush-valve.

The power station contains two submerged sets whose turbines are designed for a discharge of 12·5 cu. m. Each set is protected by an electrically controlled gate, 3·6 m. by 3·6 m., which permits the flow to be checked when the turbine is stopped, this always being of great importance when closure is effected by means of the runner vanes only. These gates can also be lowered by gravity, thus acting as emergency gates since they prevent extended racing runs, as for example in case of a.c. failures. The draught-tubes are of the straight type and can be closed by cofferdam gates. Above the draught-tubes, there are two rooms, of which the lower one contains the governing gear, together with the battery and its d.c. converter, and the upper one the control panels, as well as the hoists of the stop-valves. An old gantry-crane, obtained from a disused railway station, is in service to the handle the equipment of the station plant and transformer. Experience has shown that the erection of a generating set of the type introduced at Castet, from the time it reached the yard until ready for operation, did not take more than about 10 hours, and an even shorter time would be needed for dismantling. The Castet plant is remotely controlled from the Hourat power station, 14 km. upstream. (H. Chamayou, *La Houille Blanche*, Vol. 9, No. 2, March-April 1954, p. 119, 11 pp., 5 ff.)

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